DECEMBER 84 - FEBRUARY 85 PRICE 75p

Electronics

THE MAPLIN MAGAZINE

★ LASERS & FIBRE OPTICS IN TODAY'S WORLD ★

★ GAS ALARM DETECTS ALL EXPLOSIVE GASES ★

★ HOW TO MAKE YOUR LOUDSPEAKERS LOUDER ★

★ 4-CHANNEL MODEL RADIO CONTROL SYSTEM ★

★ SAFETY WITH ELECTRICITY IN THE HOME ★

December 1984 to February 1985
Volume 4 Number 13

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THE MAPLIN MAGAZINE

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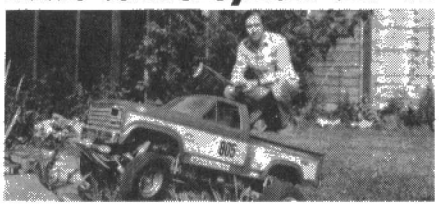

A 4-channel radio control system having two on/off channels and two proportional pulse-width-modulated channels. The system does not require an operating licence as it operates at low power on the 27MHz band just below CB frequencies.

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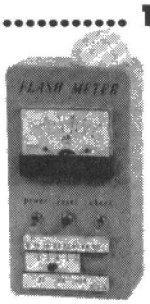

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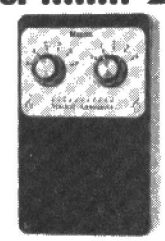

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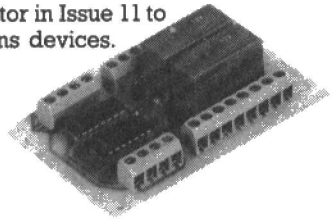

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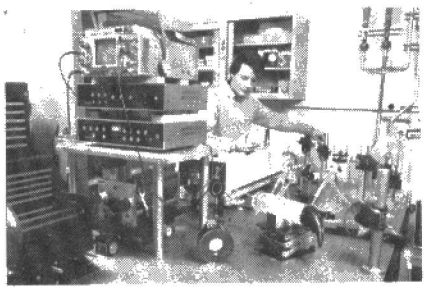

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Cover: Background photograph supplied by British Telecommunications PLC.

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Published by	Maplin Electronic Supplies Ltd.
Typesetting by	Essex Process Engraving Co. Graphic House, Stock Road, Southend-on-Sea, Essex.
Printed by	Eden Fisher (Southend) Ltd., Stock Rd, Southend-on-Sea, Essex.
Distributed by	Spotlight Magazine Distribution Ltd., 1-11 Benwell Rd, London N7.

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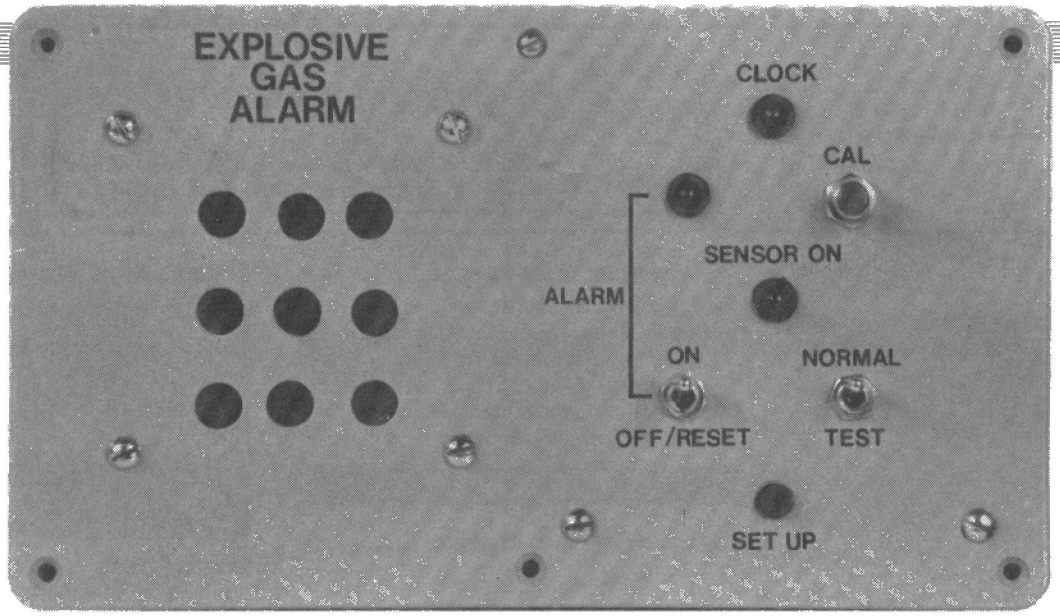


★ Operates from 12V battery ★ Very low average current consumption
★ Detects all common explosive or inflammable gases ★ Loud strident alarm

EXPLOSIVE GAS ALARM

by Robert Kirsch

Dangerous gas leaks, particularly in confined spaces, causing explosions and fires, are becoming a more common occurence, usually damaging property and often maiming or even killing people. The Maplin gas detector has been designed to prevent the build-up of these gases by sounding a loud alarm before sufficient gas has leaked to cause a damaging explosion. The sensor used consists of two separate units, the sensor itself and a reference compensator. Both elements are connected in series and used to form two legs of a Wheatstone bridge. The two elements have similar resistance under normal conditions and vary equally with changes of ambient temperature, maintaining the bridge in balance. The presence of an inflammable gas causes the sensor element to increase in temperature, due to the oxidization of the gas on the surface of its platinum heating element. This increase in temperature causes an increase in resistance of the element and thus the bridge becomes unbalanced, the detection of which causes the alarm to sound.

The fairly high current (about 400mA) required by the sensors and their associated circuitry make it undesirable to have the sensors permanently energised, particularly when installed in a boat or caravan where the power is supplied from a 12V battery. This problem is overcome by testing for gas once every 5 or 6 minutes and latching the alarm on when gas is detected. This test period is adequate because in most cases the build up of gas, due to a leak, is fairly slow and the alarm should operate well before a dangerous level is reached.

The system will detect all common explosive or inflammable gases such as Butane, Propane, Methane, Town Gas, Natural Gas, and Petrol Vapour. The sensors are enclosed in double wire mesh housings to prevent any chance of the sensor itself igniting any gases encountered.

How It Works

The Wheatstone bridge, previously mentioned, consists of R2, R4, RV1, and the two sensing elements. The balancing of the bridge is performed by adjusting RV1. The CAL switch (S1) is used to unbalance the bridge by a small amount, simulating the presence of a small amount of gas, this being used in setting up the alarm for maximum sensitivity. The state of the bridge is monitored by the dual op-amp, IC1a and IC1b, whose output is used to turn on TR3 under alarm conditions. IC4 forms a dual oscillator to produce the warbling alarm tone, and its output is fed to TR4 which drives the Piezo tweeter which provides the audio output. The alarm, when activated, latches on and sounds continuously until reset by the action of S3, which also disconnects the speaker for testing purposes. Latching is performed by connecting the positive voltage fed from the collector of TR3 (under alarm conditions) back to the inverting input of IC1a via D3, D4 and R5.

The sequence timing of the alarm is carried out by IC3, which is a 14 stage ripple counter with built in oscillator. The frequency of the oscillator is determined by R17, C3 and C4 running at about 1 cycle every 4 seconds. The various outputs from IC3 are used to control the switching regulator TR1 and to enable the monitor circuit via IC2, R13 and D5. The sensors require at least 20 seconds to settle down after power is applied before a test can be made and for this reason the sensors are powered for about 80 seconds per test cycle, but the alarm is only enabled for the last 40 seconds of this period. The time between tests can be altered by selecting various straps but under normal conditions the shortest period is recommended. (Link A to B). The sensors require a stable supply independent of variations of the incoming supply voltage, this is achieved by the 5V regulator (REG1) which provides the

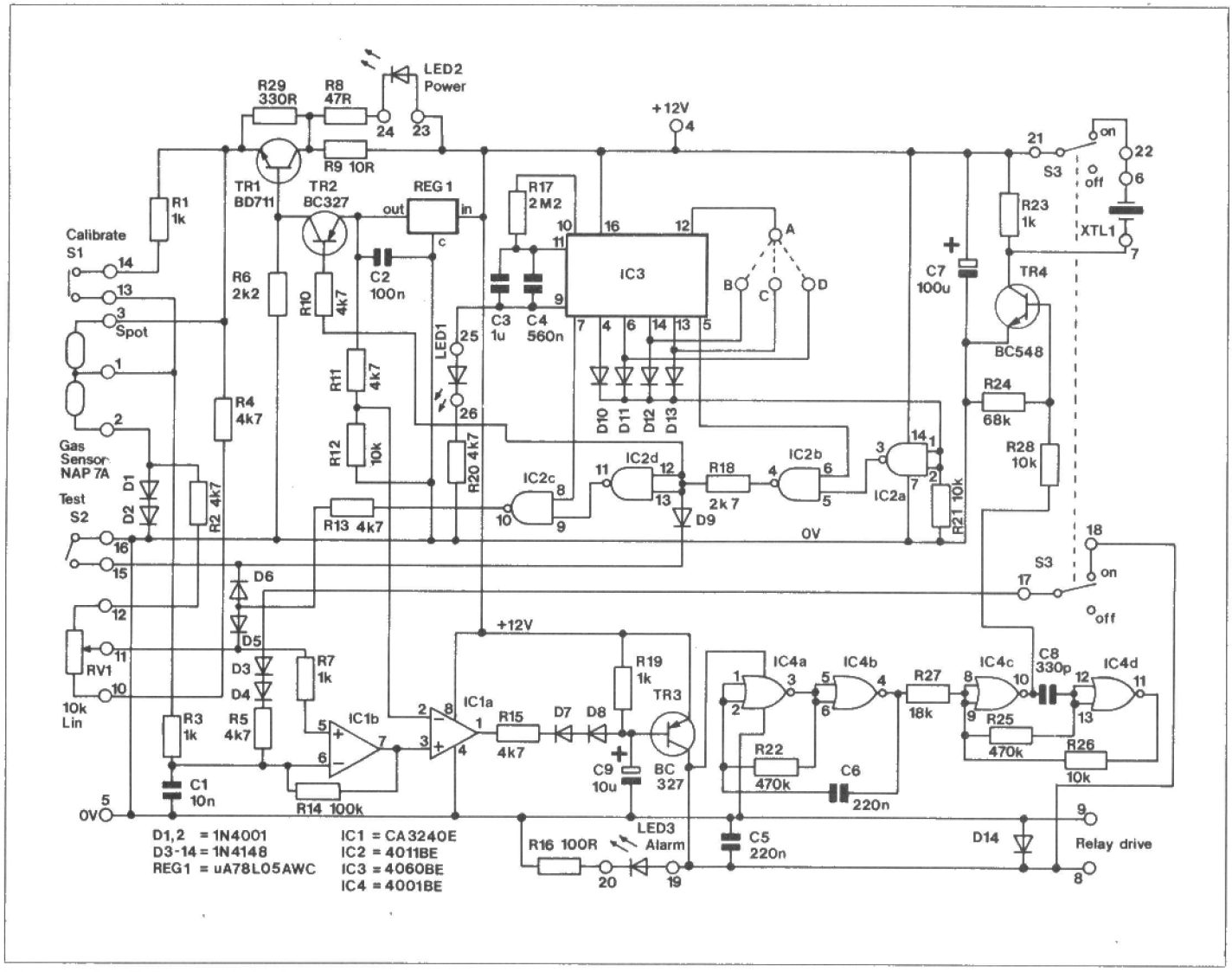


Figure 1. Circuit diagram of Gas Alarm

base current for the power switching transistor (TR1) via TR2, which forms part of the control circuit, fed from IC3.

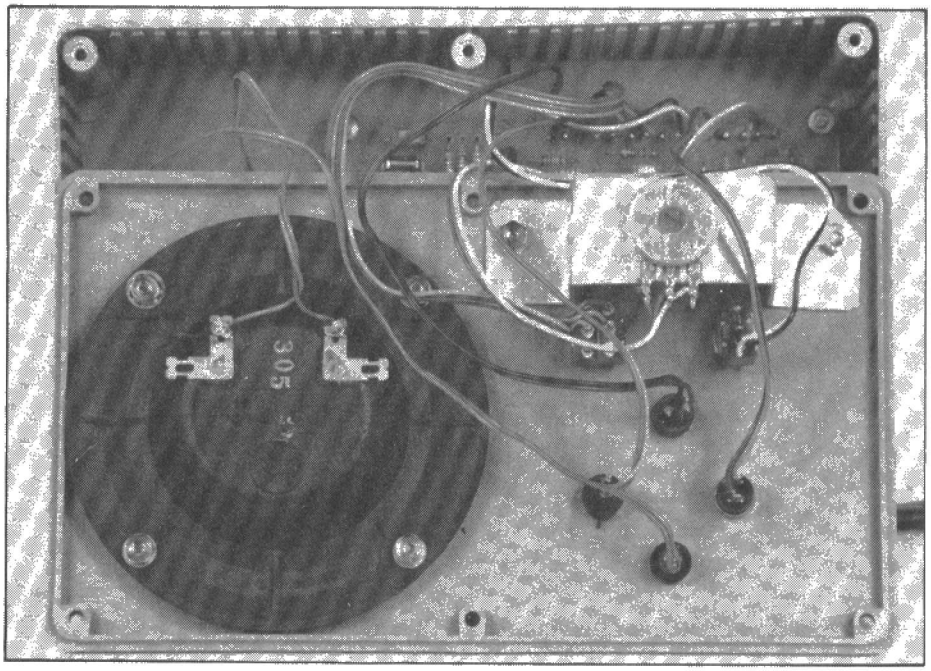
The TEST switch (S2) overrides the timer connecting power to the sensors and also enabling the alarm circuit. LED2 lights whenever current is drawn by the sensors and will be on continuously when S2 is in the TEST position. Note that when the alarm is working, LED2 will only be on for the 80 seconds of the test period during each test cycle. LED3 gives an indication of an alarm even when the ALARM CANCEL switch (S3) is operated and is used for setting up purposes. LED 1 flashes at clock rate and is an indication that the timer is running.

Construction

Construct the circuit board referring to the Parts List and component overlay on the board. Ensure the correct polarity of all diodes, transistors, integrated circuits and electrolytic capacitors. The sensors should be mounted carefully on their board, avoiding excessive heat and making sure that the one marked with the spot is in the correct position. The required amount of cable should be connected to the sensor board at this stage but not terminated on the main board before testing.

Setting Up and Testing

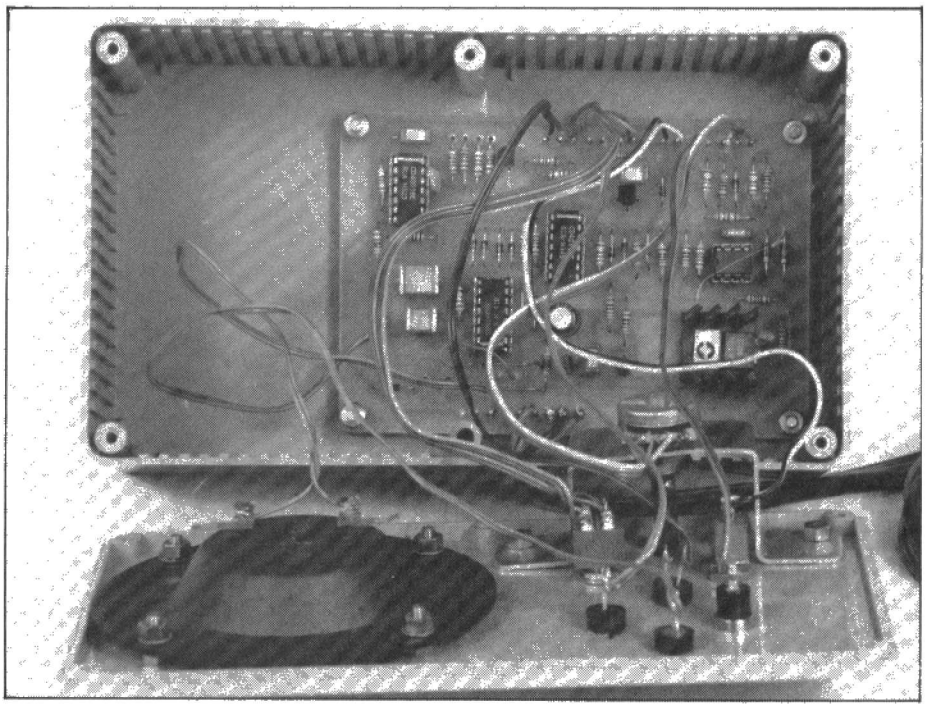
Connect the 10 ohm test resistor provided with the kit in place of the sensors (between pins 2 and 3). Switch S3 to ALARM OFF and S2 to TEST. Connect 12-24V to the unit and observe LED1; this should flash regularly at about once every 4 seconds. Connect a multimeter; set to a range that reads up to 10V, between −V battery supply (pin 5) and pin 3 (also connected to one end of test resistor). A reading of between 4.1 and 4.6 volts should be obtained at this point. Transfer the meter to pin 2; a reading of 1.4 to 1.8 volts should be measured.



NOTE, if these readings are not correct DO NOT connect the sensors. WARNING, the test resistor will become HOT during this test.

When the above conditions are correct, disconnect the supply and remove the test resistor. Connect the sensor cable ensuring correct location of wires. Re-apply power and check that LED2 (Green) is on. When current is first applied to the sensors, a slight smell of burning may be noticed; this is quite normal. Turn RV1 fully clockwise; in this position LED3 (Red) should be out. Wait 20 seconds then rotate RV1 slowly anti-clockwise until LED3 is just on. Very carefully rotate RV1 clockwise again until the LED is just extinguished but can be made to light by pressing the CAL button. This process must be done with extreme care if maximum sensitivity is to be obtained.

Disconnect the power for about 1 minute. When the power is re-applied, the ALARM LED should light immediately but go out after a maximum of 30 seconds. If the LED remains on after this period, slightly re-adjust RV1 anti-clockwise but make sure the above test conditions are met. Check that the alarm sounds when the ALARM LED is alight and S3 is normal.The unit is now ready for use, but a further test may be carried out under actual working conditions. Place the sensor board in a container of about 5 litres capacity (e.g. a large ice-cream container) and arrange a loose fitting card lid to cover it. Fill a small container of about 65cc (e.g. a small aerosol lid) capacity with butane from an ordinary gas cigarette lighter and cover with card or a sheet of paper. With the alarm set, carefully slide the lid from the small container and pour the gas (Butane is heavier than air) into the large container; then cover this container. The alarm



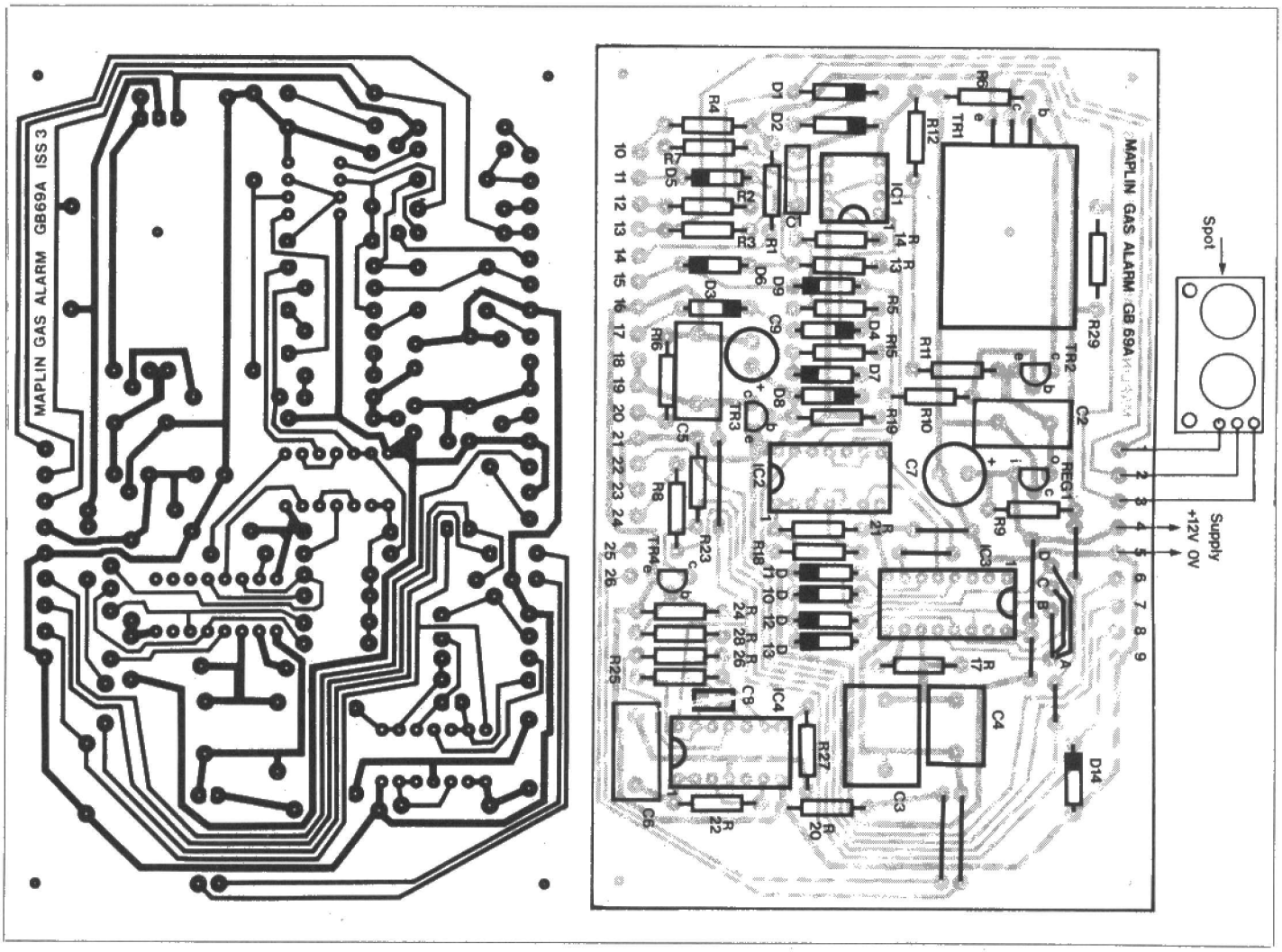


Figure 2. Track layout of main PCB

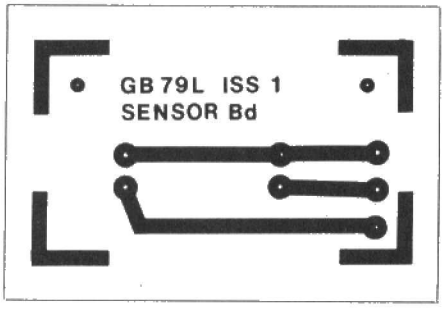


Figure 3. Gas Sensor PCB

should sound within a maximum of 6 minutes and remain latched until reset by S3. WARNING, do not carry out this test near a naked flame, near incandescent material or when smoking!

Installing the Alarm

The sensor board may be located up to 5 metres from the main alarm unit. Most common explosive gasses are heavier than air and therefore the sensors should be located at the lowest point where gas will collect. A free flow of air must be provided around the sensors and they must be kept free from contamination by oil or water. This alarm system is primarily designed for use in boats where power is supplied from a battery,

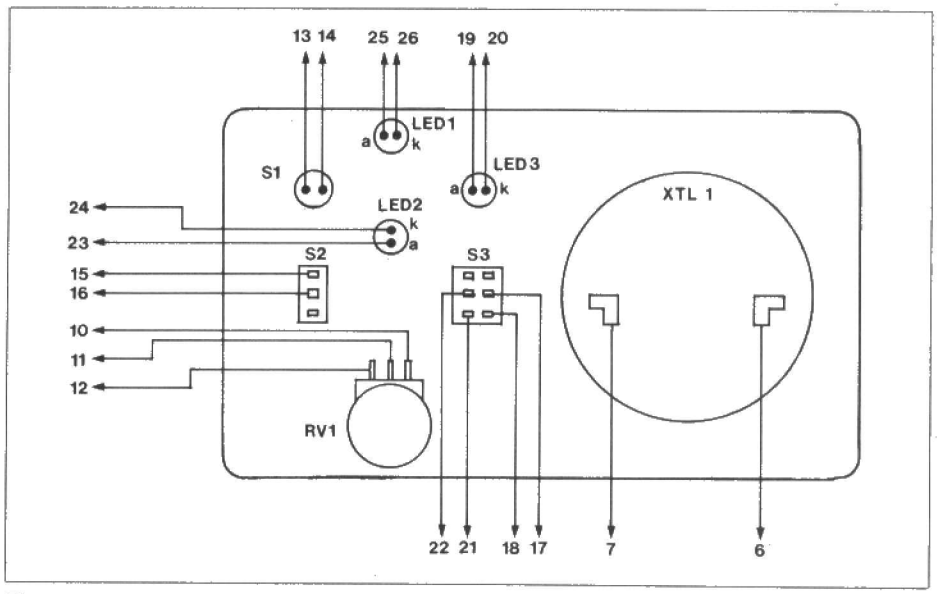
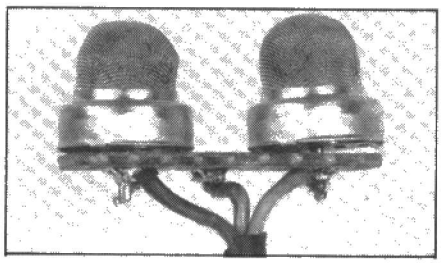


Figure 5. Wiring diagram



but it could also be used in the home when fed from a suitable mains power supply (requiring about 800mA at 12 volts). Finally, when gas is encountered, remember to ventilate the area well and beware of any form of ignition from naked flames, cigarettes, hot surfaces, sparks from electrical switching or other causes.

PARTS LIST FOR EXPLOSIVE GAS ALARM

RESISTORS: All 0.4W 1% Metal Film unless specified.

R1,3,7,19,23	1k	5	(M1K)
R2,4,5,10,11, 13,16,20	4k7	8	(M4K7)
R6	2k2	1	(M2K2)
R8	47Ω	1	(M47R)
R9	10Ω ½W Carbon	1	(S10R)
R12,21,26,28	10k	4	(M10K)
R14	100k	1	(M100K)
R16	100Ω	1	(M100R)
R17	2M2	1	(M2M2)
R18	2k7	1	(M2K7)
R22,25	470k	2	(M470K)
R24	68k	1	(M68K)
R27	18k	1	(M18K)
R29	330Ω ½W Carbon	1	(S330R)
RV1	Pot Lin 10k	1	(FW02C)
RT	10Ω ½W Carbon (Test Resistor)	1	(S10R)

CAPACITORS

C1	10nF Polycarbonate	1	(WW29G)
C2	100nF Polycarbonate	1	(WW41U)
C3	1μF Polycarbonate	1	(WW53H)
C4	560nF Polycarbonate	1	(WW50E)
C5,6	220nF Polycarbonate	2	(WW45Y)
C7	100μF 25V PC Electrolytic	1	(FF11M)
C8	330pF Ceramic	1	(WX62S)
C9	10μF 63V PC Electrolytic	1	(FF05F)

SEMICONDUCTORS

D1,2	1N4001	2	(QL73Q)
D3-14 inc.	1N4148	12	(QL80B)
TR1	BD711	1	(WH15R)
TR2,3	BC327	2	(QB66W)
TR4	BC548	1	(QB73Q)
REG1	μA78L05AWC	1	(QL26D)
IC1	CA3240E	1	(WQ21X)
IC2	4011BE	1	(QX05F)
IC3	4060BE	1	(QW40T)
IC4	4001BE	1	(QX01B)

MISCELLANEOUS

LED1	LED Yellow	1	(WL30H)
LED2	LED Green	1	(WL28F)
LED3	LED Red	1	(WL27E)
	LED Clip	3	(YY40T)
S1	Push Switch	1	(FH59P)
S2	Sub-min Toggle A	1	(FH00A)
S3	Sub-Min Toggle E	1	(FH04E)
	Gas Detector Sensor	1	(FM87U)
	Gas Detector PCB	1	(GB69A)
	Sensor PCB	1	(GB79L)
	Veropin 2145	1 pkt	(FL24B)
	Heatsink Vaned	1	(FL58N)
	8-pin DIL Socket	1	(BL17T)
	14-pin DIL Socket	2	(BL18U)
	16-pin DIL Socket	1	(BL19V
XTL1	Direct Radiant Piezo	1	(WF54J)
	Hook-up Wire	1 pkt	(BL00A)
	Bolt 6BA x ½ inch	1 pkt	(BF06G)
	Nut 6BA	1 pkt	(BF18U)

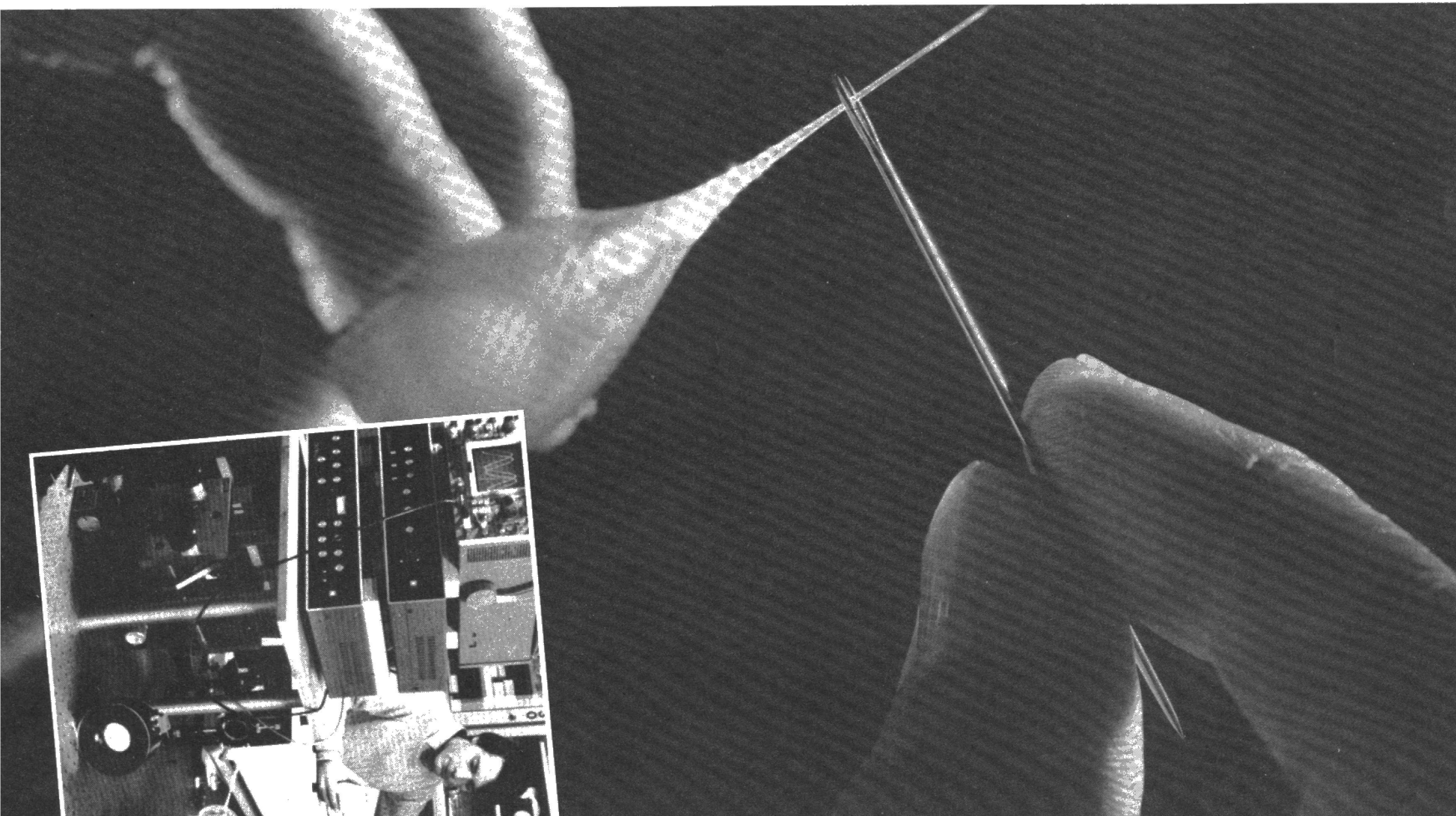
OPTIONAL ITEMS

Case	1	(LH62S)
Knob K7B	1	(YX02C)
Fixings	As required	

A Kit of parts is available (excluding Optional items).
Order As LK60Q (Gas Alarm Kit) Price £23.95

The following parts used in this project are also available separately, but are not included in our current catalogue.
GB69A Gas Detector PCB Price £2.45
GB79L Sensor PCB Price £1.15
FM87U Gas Detector Sensor Price £6.99

LASERS & FIBRE OPTICS



by D. Stewart

The laser beam sliced through the sheet of metal and James Bond's legs nearly parted forever, in the film. Fortunately, lasers have been used to do more good than harm. They have been used for instance in medicine to repair the retina of the eye without the use of stitches. Also in entertainment to produce three dimensional holography at discos and they will probably be the basis of three dimensional television. So what are the principles that make lasers possible?

Light Sources

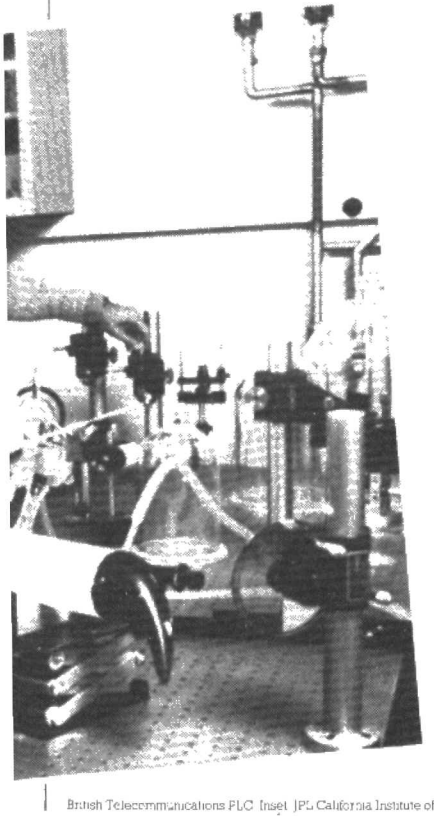
We could use a light bulb but we would not be able to switch it on and off as rapidly as we would like so we have to turn to semiconductor devices. There are two, the light emitting diode (LED) and the laser (light amplification by stimulated emission of radiation).

Both these devices work the same way. Referring to the energy band diagram of Fig. 1, if a p–n junction is forward biased, the hole-electron pairs recombine and a photon or packet of light is released. The main difference between LED's and lasers is that in LED's, the electrons fall from the conduction band to the valence band spontaneously while lasers have to be stimulated.

The wavelength emitted depends on the gap between the valence and conduction bands and for gallium aluminium arsenide (GaAlAs), this is 0.85μm which can be changed slightly by altering the percentage of aluminium.

Lasers

Here we will deal only with semiconductor lasers; ruby and gas lasers are mentioned in Applications. The chips are about 400μm square with perfectly perpendicular ends and mirror surfaces.



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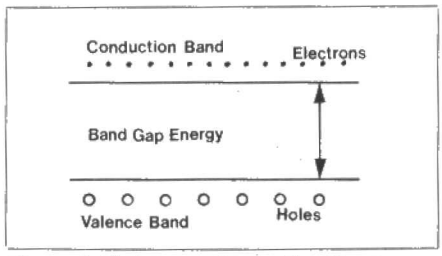


Figure 1. Valence – Conduction Bands

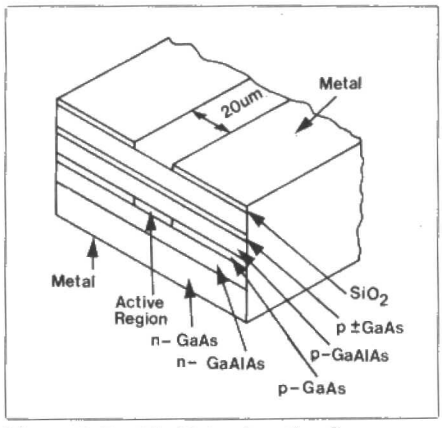


Figure 2. Double Heterojunction Laser

Now what could be prettier! Fig. 2 shows a double heterojunction with alternate layers of GaAlAs (Gallium Aluminium Arsenide) and GaAs. Early lasers were homojunctions and heterojunctions.

The layer of GaAlAs has 5% aluminium in the active region and 35% in the passive region. This prevents fracture should the device expand from the heat generated. Copper heat sinks are soldered onto the laser using indium as the solder since indium is soft and flexible.

When a spontaneously emitted photon is reflected by the end mirror and meets an electron about to emit another photon, stimulated emission occurs and more photons are released. This makes lasers brighter than LED's and lasers can operate for about eleven years at room temperatures giving an output of about 5mW.

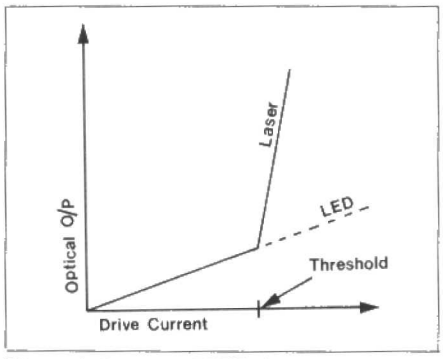


Figure 3. Laser and LED Outputs

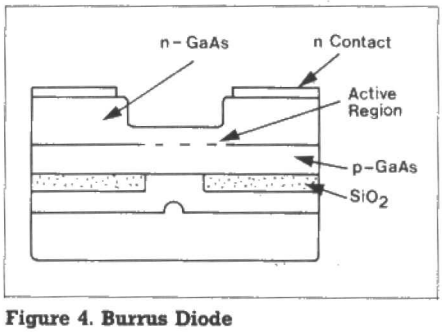


Figure 4. Burrus Diode

The bandwidth of lasers for information carrying purposes is also wider than that of LED's. This is because the line width is narrower than that of LED's hence increasing the useful bandwith. The spectrum emitted by an LED could be as wide as 20nm (nanometres: 1nm = 10^{-9}m), whereas the line width of a laser is only 1nm. The emission from a laser is more faithful because the lasing feature enables photons to stimulate other photons of the same wavelength.

The stripe is the active region and helps to reduce the threshold current (Fig. 3). The threshold current is the current at which lasing starts and the heterostructure geometry also helps to reduce this threshold. In practice the strip is between 5μm and 20μm but what is more important is that the refractive index of the stripe must be uniform to give a straight line in the characteristic.

LED'S

These operate in the infra-red range, at 0.85-0.95μm and are similar to lasers i.e. not pumped or stimulated. The LED's efficiency can be increased by creating a well and such high radiance diodes are called Burrus diodes (Fig. 4).

Even more efficient than Burrus diodes are edge light emitting diodes (ELED's). The sandwiched layers are the same as those of a laser so they are cheap to manufacture.

Instead of emitting light from the well, ELED's emit light from the edge in the same manner as lasers. Even the stripe is etched in the insulated oxide layer but with one big difference. The stripe does not appear over the full length of the chip in the ELED and therefore the region without a stripe is an absorption region. Light is absorbed here so no feedback takes place to produce laser action.

Light Detectors

Light travels in packets of energy called photons which are related to the velocity and wavelength of light as follows:–

$$\text{Energy per photon} = \frac{hc}{\lambda}$$

where c = velocity of light, λ = wavelength of light and h = Planck's constant.

Detectors operate in exactly the opposite manner to light emitters i.e. in light emitters, electrons were releasing light but in detectors, light releases electrons. These electrons move from the valence band to the conduction band of Fig. 1 and this can happen only if the energy given up by the photon is equal to the energy of the band gap. So in order to detect a source radiating at 0.85μm we need a detector that is sensitive to the same wavelength.

Two kinds of detector are available; the avalanche photodiode (APD) and the positive intrinsic negative (PIN) diode.

Good diodes will have the following characteristics: low capacitance, low dark current, fast response and high efficiency. Dark current means that the

diode conducts even when light is not falling on it hence it will be difficult to detect a weak signal. Low capacitance decreases the time taken by carriers to cross the junction.

The efficiency is measured as follows: if say 100 photons fall on the detector, releasing 90 electrons, then the efficiency is 90%. At least 21 photons must fall on the detector to reproduce a digital one.

Avalanche Photodiodes

Fig. 5 shows the voltage–current characteristic of an APD and the forward current is the same with and without light. In the reverse direction, the dotted line shows current flowing in the dark.

For communications purposes lasers and detectors are operated at certain wavelengths that are optimum for optical fibre as we shall see later. These wavelengths are 0.85μm, 1.3μm and 1.55μum and silicon APD's are suitable for operation at 0.85μum but germanium ones are required for use at the other two wavelengths even though germanium ones have high dark currents.

One drawback of APD's is that they need high reverse biases typically 100V and there is the difficulty of running such high DC voltages along a route. Nevertheless, APD's have gains of 10^3, but those with lower gains are adequate.

An APD is shown in Fig. 6. The junction is placed near the surface so that the avalanche effect can be started by electrons in the heavily doped n+ region. But the strong field could break down the junction and a guard ring is required.

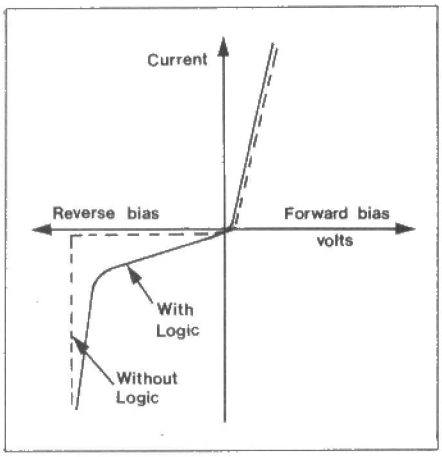


Figure 5. APD Responses

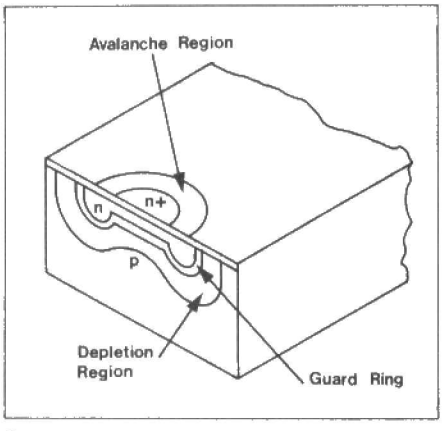
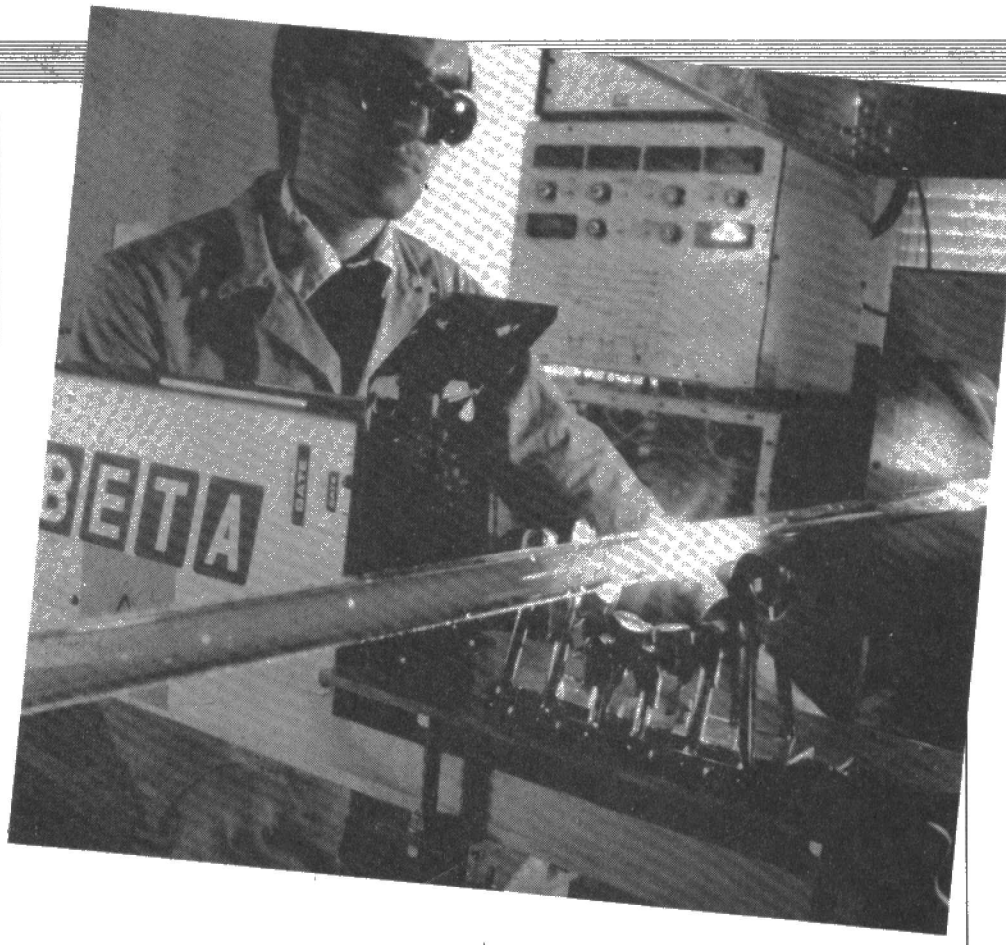


Figure 6. Avalanche Photodiode



PIN Diodes

The intrinsic layer is a low doped n type layer. We mentioned the need for low capacitance earlier and this can be achieved by increasing the width of the intrinsic layer. However, a limit is reached when the leakage current starts to increase and a suitable compromise is an i-region of about 100μm in a chip size of about 400μm square.

A phenomenon called the reach-through effect is used for rapid collection of electrons. It works like this. Take a PIN diode and apply a reverse bias, then shine a photon of light on it. In a p-type material holes are the majority carriers and electrons the minority carriers (opposite for n-type material). Under the influence of the reverse bias, the minority carriers flow across the junction but the majority carriers do not. This has the effect of clearing the carriers to the majority sides hence creating a depletion region right through to the heavily doped substrate.

PIN diodes need an FET amplifier as the next stage since the signal is weak but they have a faster response than the APD's.

Optical Fibres

Having discovered a light source and a suitable detector, it only remains to connect the two with a piece of glass. Not any old glass, a quick flash in window glass will get us nowhere. All the impurities need to be removed.

So we get a strand of pure fibre and connect the source to the detector, switch on the source and get nothing at the detector. Why? Because the light is very quickly reflected out of the fibre. Now we get clever and cover the fibre with more glass of a lower refractive index so that the rays are reflected back into the fibre.

This is much better but still has its drawbacks. To start with, no light emitting source emits a pure wavelength, though the linewidth of lasers is narrower than say the linewidth from a searchlight. So if we have several wavelengths close to each other and modulate them, the bandwidths would overlap and this would limit the useful bandwidth.

The same sort of thing also happens when light bounces down a fibre. There are three modes of propagation down a fibre and these are shown in Fig. 7.

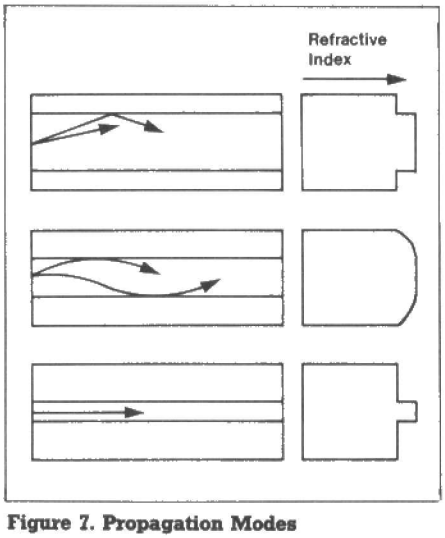


Figure 7. Propagation Modes

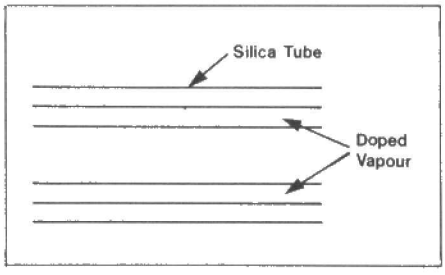


Figure 8. Vapour Deposition

Multimode Fibre

Rays travelling parallel to the axis will arrive at the detector quicker than those that have been bounced off the edges and once again this reduces the useful bandwidth. The core of multimode fibres is usually about 50μm and the refractive index about 1.5% higher than that of the cladding. Now we can see why we have been speaking of propagation in terms of wavelength instead of frequency. It is easier to compare wavelengths with the fibre dimensions just as we do in mocrowave waveguides and optical fibre is after all a light waveguide.

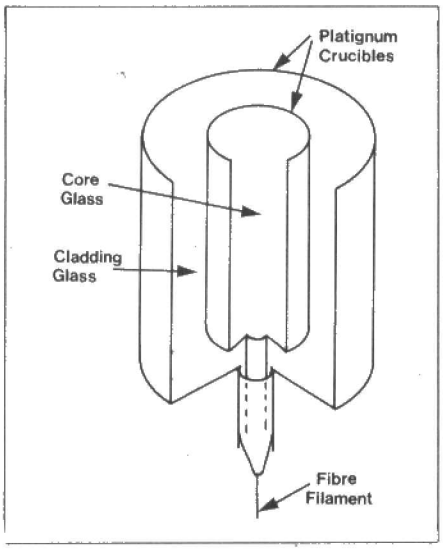


Figure 9. Double Crucible Method

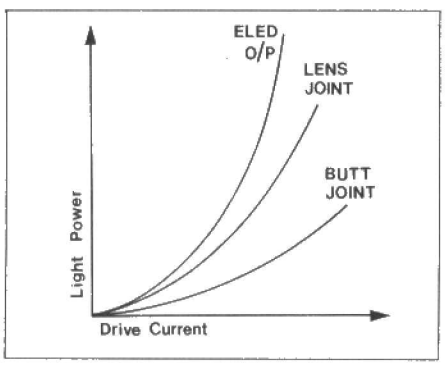


Figure 10. Coupling Efficiency

Graded Index Fibre

Instead of bouncing the waves off the cladding we can speed them up by making the refractive index between core and cladding gradual instead of a step.

Monomode Fibre

– or Singlemode as the Americans call it. If we select just one wavelength to propagate, then the core need be only about 6μm wide. It is difficult to launch power into a fibre this small and source to fibre connections need to be carefully aligned so as not to waste power.

Losses in Fibres

Care needs to be exercised during manufacture not to introduce physical deformities or chemical impurities which would cause absorption or scattering of the signal.

However impurities cannot be removed entirely and water for instance can absorb signals at 0.95μm which is near the operating region of communications systems.

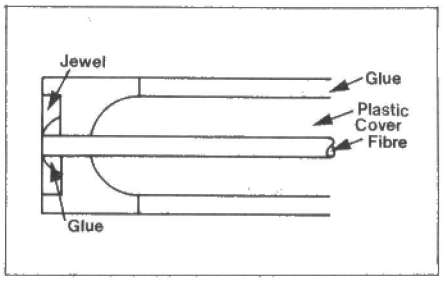


Figure 11. Butt Joint

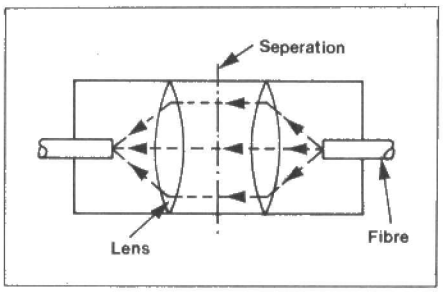


Figure 12. Lens Joint

Absorption can also take place due to metallic impurities like iron, chrome, titanium, cobalt etc, the absorption depending on the amount of impurity and their oxides. Glass can be coloured green by introducing iron as an impurity, sapphires are blue because of titanium and rubies are red because of chrome impurities. Absorption can also take place when molecules vibrate within the fibre and interact with the rays.

Scatter losses can be caused by bubbles in the glass, either in the raw material or during manufacture of fibres and these need to be boiled off. Scatter can also be caused if the refractive index of the fibre varies over small distances; this is called Raleigh Scatter and at 0.85μm the loss can be up to 2dB/km.

Fibre to Fibre Jointing

Just as source and fibres can be butt jointed, fibres can be butt jointed to other fibres. A watchmaker's jewel is mounted in a stainless steel ferrule, Fig. 11 and the fibre inserted in a hole in the jewel, held in place with adhesive and polished flat with the surface of the ferrule. Watchmaker's jewels are not too expensive and holes can be drilled more accurately than in metal.

Lens terminations can also be used as for source to fibre connections. In addition the lens mountings can be made in a factory and ready to use in the field when the fibre is laid. These are prepared in two halves with the fibre at the focal point of the lens, Fig. 12.

The two methods above are suitable when new routes are laid but what if a fibre is damaged and required to be reconnected? The ends need to be cut vertically and the cores aligned using a microscope. Then they can be fused using a hot wire heater or they can be inserted into a glass sleeve Fig. 13, about 10mm long. One fibre is inserted and the sleeve collapsed, then the other fibre is cemented in.

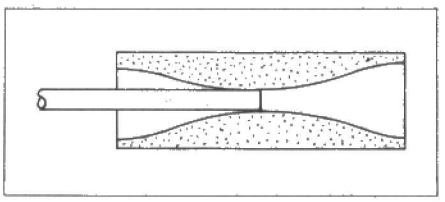


Figure 13. Fibre in Glass Sleeve

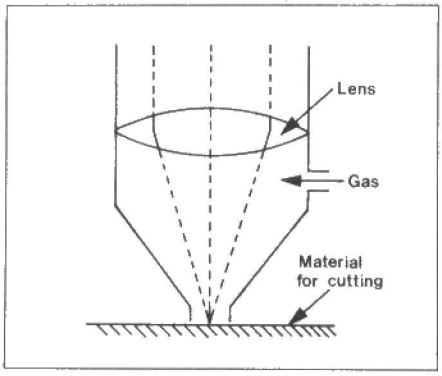


Figure 14. Laser for Cutting

Laser And Optical Fibre Applications

Perhaps the best known application of lasers is in the field of eye surgery. Previously a xenon-arc lamp was used, but because of the long exposure time, anaesthetic was required. In addition the spot size focuses down to about 800μm, but lasers can provide a smaller spot, about 50μm, which is useful in such confined areas. Also a pulse of 1 Joule from a Ruby laser for 300μsec is sufficient and the eye does not require clamping since the time is so short.

Lasers can also be used for cutting, drilling and welding. For cutting, a carbon dioxide laser is used since it produces higher power than a ruby laser and aluminium for aircraft can be cut some 70% cheaper than by conventional means. A gas jet can be fed with the beam, Fig. 14, to blow away the swarf or if the swarf is hot, oxygen can be used to burn it.

Drilling holes less than 250μm in diameter with mechanical drills is difficult and usually ends in a broken drill bit. With lasers however, holes down to 10μm can be drilled quite easily and the Swiss watch industry drills holes in ruby stones using flash-pumped neodymium-YAg lasers.

In microelectronics, wires as thin as 10μm may need welding. In addition these may be dissimilar metals or in inaccessible areas like in a glass envelope or near heat sensitive areas and lasers are a useful friend.

When a spacecraft re-enters the Earth's atmosphere, the heat generated around it is a barrier to electrical communication but transparent to optical waves so contact can be maintained during those crucial minutes. Lasers have also been used to study movements of the Earth's crust in order to predict earthquakes. The USA launched the Laser Geodynamics Satellite (LAGEOS) which was 60cm in diameter and weighed 411kg. It was at an altitude of

5,800km and had 426 retroreflectors, which are corners of glass cubes, hence the incident and reflected rays will be of the same length if the Earth's crust has not moved.

Retroreflectors can be used in tracking systems which are lighter and cheaper than radar. Light detection and ranging (LIDAR) has been used to study the atmosphere. The dangers of contaminating the atmosphere with aerosols and exposing us to radiation is well known. Therefore studies have been made of the atmosphere to detect aerosols which would produce kinks at X and Y of the curve of Fig. 15.

The main advantages of lasers then, are: small focussed image, accurate positioning, exact control of energy, operation in inaccessible areas or near heat sensitive areas without contamination.

Optical fibres are every bit as useful as lasers. These are useful in areas of high electrical noise, say for monitoring factory processes where machines are starting and stopping all the time. As an extension of this use they can be used for measuring high currents where the usual wire leads could result in an accident. Here Faraday's principle is used: the rotation of the plane of polarization of a light beam is proportional to the field strength and the length of the path through the field.

Manufacture

Manufacture of Light Sources.

The old method was to diffuse donor and acceptor elements into a substrate as is done in the manufacture of transistors, but the modern technique is liquid phase epitaxy.

A source crystal of GaAs is placed on top of aluminium and gallium in a crucible. A weight is placed on top and heat applied to the crucible. At 800°C, part of the source slice dissolves in the melt which reaches equilibrium. If the temperature is then dropped to 780°C, the equilibrium is disturbed and a GaAlAs layer is deposited on the source slice.

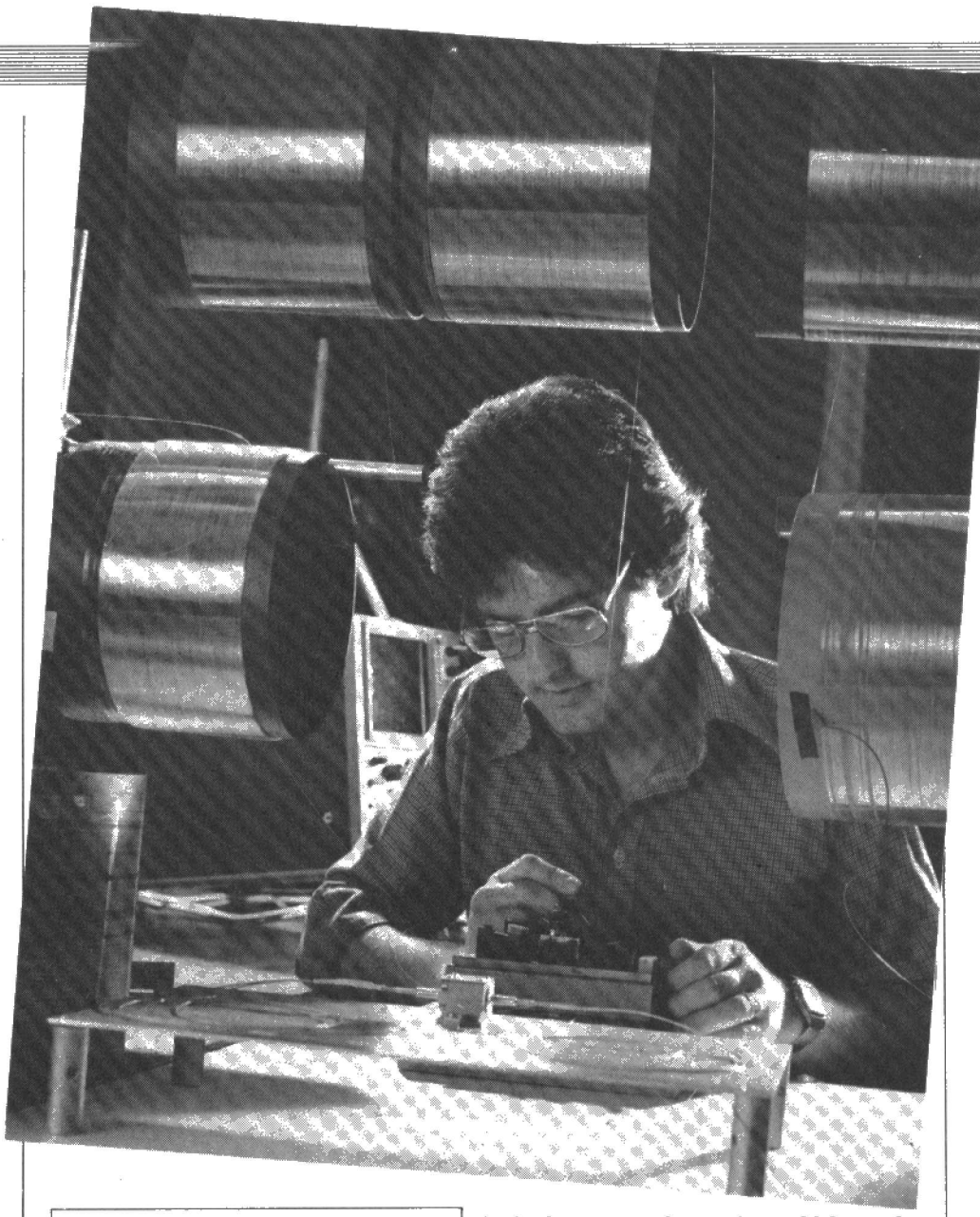
In this way several different layers can be grown including depositing a layer of GaAlAs on a substrate.

Manufacture of Fibres

The main techniques are vapour deposition and the double crucible method.

The vapour deposition method uses a flame to deposit layer after layer of core, then cladding on a rotating mandrel. This is then collapsed into a fibre. A starting rod could be used instead and the vapour applied to the end to build up the rod.

Fig. 8 shows the Corning method of vapour deposition where an oxygen flame is used to deposit a layer of pure silica inside a tube. This will form the cladding. To form the core, silica doped with aluminium, titanium, germanium or phosphorous oxide can be used. This is deposited as the next layer and the whole thing collapsed into a fibre. To form graded index fibre, glasses with suitable dopants are chosen so that the dopants diffuse through the glass uniformly.



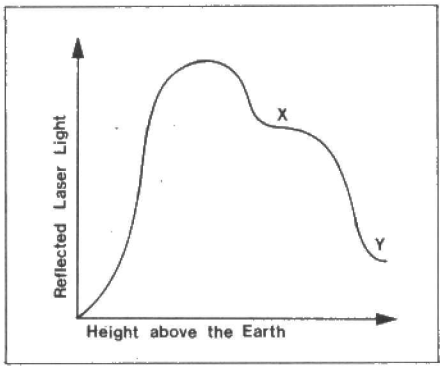


Figure 15. Aerosol in the Atmosphere

The double crucible method is shown in Fig. 9. The glass containing dopant will form the core and is placed in the inner crucible. Pure glass will form the cladding and is therefore placed in the outer crucible. The filament is pulled gently and a fibre of the correct composition is formed.

One of the problems of producing pure glass was that the glass was absorbing impurities from the platinum crucible. This can be overcome by RF induction heating, where a 5MHz field is created through the liquid glass which is at a temperature of 1300°K. The crucible is then not as hot as it would be and a silica crucible can be used. Any bubbles are then driven out by boiling and the pure glass can be used for making fibres.

Jointing

Source to Fibre Joints

A fibre can be brought in close contact (butt jointed) with an emitting source and a 50μm fibre will fit into the well of a Burrus diode. However, some energy does escape particularly in the case of edge emitters in contact with fibres. These losses can be reduced by using a lens to focus the energy into the core of the fibre. Fig. 10 shows the coupling efficiency of a lens compared to a butt joint.

Fibres have been used in flowmeters where a fibre is dipped in the liquid and the fibre vibrates at a rate proportional to the flow of the liquid. A further application of the fibre in liquid is in hydrophones for listening in water.

Optical fibres have been nearly as useful as lasers for getting into inaccessible areas. They have been used in industry for illuminating and examining areas that could not be visible otherwise. In medicine bronchoscopes have been used for looking into lungs when an over-enthusiastic diner has let a piece of food go the wrong way.

Optical Fibres In Communications

Perhaps the greatest use for fibres and lasers will be for communications since the optical spectrum has such a wide bandwidth. For instance, operating at 1.5μm, gives a frequency of 3×10^{14}. If this centre frequency is modulated to provide a bandwidth of only 10%, this could carry 10^{10} telephone channels.

Typical transmission rates for optical fibres as landlines will be 2, 8, 34, 140Mbit/s, and 280Mbit/s for submarine cables. Later, for wideband networks, 565Mbit/s may be employed.

A field trial took place between Hitchin and Stevenage in 1977-80. The cable was only 7mm in diameter and contained three fibres and four copper wires around a steel centre member. Over this 9km route repeaters were spaced at 3km and the system operated at 140Mbit/s.

Optical fibre definitely has the edge over copper wire. It is light, small and cheap. It is also non-corrosive – a big advantage, since cable chambers often get flooded. It has a smaller diameter, so more can be fitted in overcrowded ducts particularly in cities. It is also cheap. The cost of coaxial cable will rise by about 5% per year. In addition the cost of copper is also dependent on world prices whereas glass has no intrinsic value and the cost of fibre will actually fall as the technology improves.

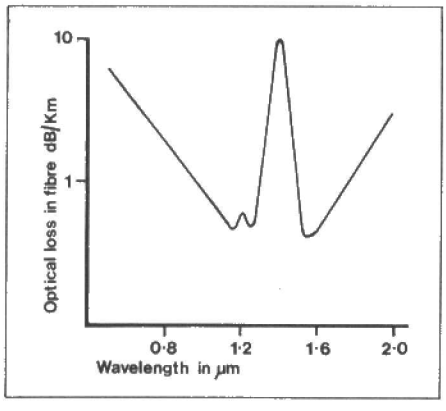
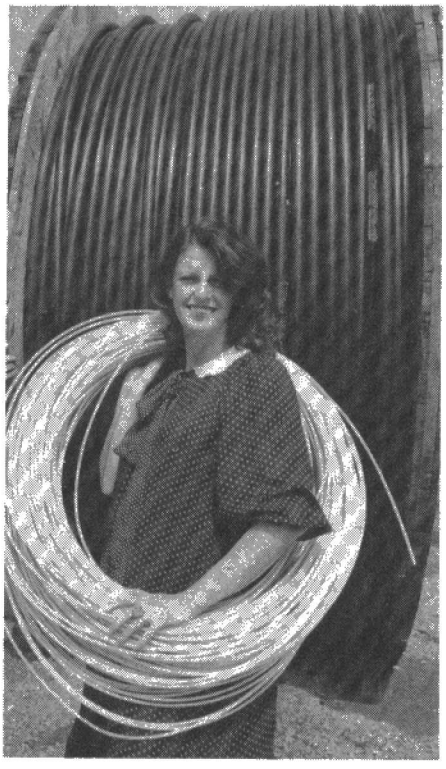


Figure 16. Optical Loss at Different Wavelengths

Optical fibre has minimum losses at certain wavelengths and a characteristic curve is shown in Fig. 16 from which it can be seen that the minimum loss occurs at 1.3μm and 1.55μm. At a transmission rate of 140Mbit/s and using 9.5mm coaxial cable, a repeater spacing of about 4.5km is possible. But optical fibre using 1.3μm and monomode operation requires



Wavelengths		·85um	1·3um	1·55um
Bandwidths	GHz/Km	2–4	6	2–4
Attenuation	dB/Km	2·5	1	0·5
Repeater spacing	Km	12	30	60

Table 1. Graded Index Fibre

repeaters at only 39km intervals which amounts to a big saving in repeater costs.

Table 1 compares operation of graded index fibre at three different wavelengths. The largest bandwidth and repeater spacing is of course available with monomode operation and will be of greatest use in submarine systems. The other fibres are not necessarily useless. Most inland routes do not require such large bandwidths and it is difficult to align the cores of monomode fibres. Since fibres are aligned by their outer diameters, the core/cladding ratio must be concentric within 1/250.

Monomode fibres can now be made with losses as low as 0.16dB/km compared to 10dB/km when work started around 1972. However 0.16dB/km is of little use if a cable is going to be broken by accident since the average loss of connectors is about 0.5dB and it is estimated that on average a cable is likely to be broken twice per kilometre over a 30 year life.

Television Links

From the characteristic curves of Fig. 3 it can be seen that LED's have a linear output and can be used for transmitting an analogue signal. Television signals are analogue since the output is varying continuously and if this needs to be transmitted without converting to digital form, an LED must be used. A laser would of course give a signal 18dB higher.

Submarine Cables

Fig. 17 shows a simple communications link, a repeater being a receiver and transmitter back to back. Two large cable systems are imminent: The UK – Belgium No. 5 and TAT8 (TAT = TransAtlantic).

The world's first international optical fibre cable will cost £7.25 million and run from the UK to Belgium in 1985. It will be 122km long and operate at 1.3μm monomode, carrying 280Mbit/s systems and providing about 12,000 circuits. It will contain three repeaters at 30km intervals which is six times the usual spacing for coaxial cables.

TAT8 will cost more than £250 million of which Britain will have the second largest share. Although it will start service in 1988, its final configuration is not known but it will use between 6600km and 9900km of fibre depending on whether it lands in three countries or seven countries. This is the first time that branching units have been used on the ocean bed. In the past submarine cables have been laid between two land masses only, before proceeding to other ones. The cable will consist of two pairs of fibres each operating digitally at 280Mbit/s and giving a capacity of 8000 telephone channels altogether.

The Future

The past ten years has seen theory turned to practice with the development of fibre of such low loss that further achievement will be of no practical value.

Lasers had reached a critical limit at 500Mbit/s beyond which the laser diode does not respond to electrical modulation. Now Siemens has come up with a technique to push this rate up to 6Gbit/s! In the past the laser has been used both as a source of light and as a transducer. The new technique is to let it glow continuously instead of switching it on and off. The modulation can then be carried out by a crystal of lithium niobiate ($LiNbO_3$).

And so to the future. Man has always been frantic in exploiting new technology like a child receiving a new toy. Technology itself is neutral; we can use lasers for eye surgery or as beam weapons in space. We are free to decide to use technology as a slave; but sometimes man ends up a slave to technology.

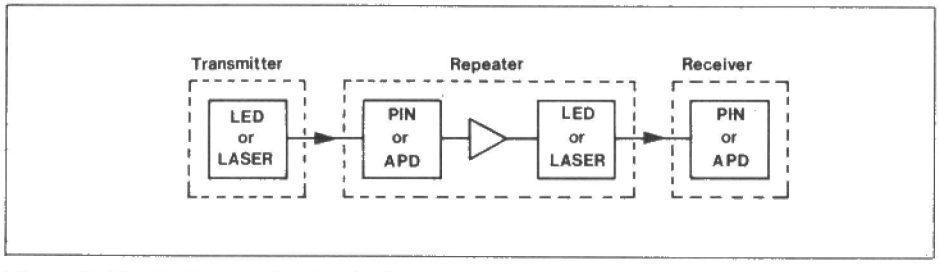


Figure 17. Simple Communications Link

Inexpensive but sophisticated electronic flashguns have been available for some years now, and they offer what on the face of it is an ideal system of lighting for many applications. In practice there are problems that can make flash lighting a little difficult to use. Probably the most formidable of these is obtaining the correct exposure. Many cameras have a built-in exposure meter these days, but in most cases the meter does not function properly with flash lighting, and a special flashgun is needed for the few cameras which do support TTL automatic flash. Ordinary automatic flashguns can often solve exposure problems, but the sensor's wide light reception angle means that it may not always give accurate results, and the number of aperture options available is usually very limited. Also, automatic flashguns are only intended to be used singly, and the use of two or more guns can easily cause under exposure due to the light from each flashgun activating the cutoff circuit of the other.

When using electronic flash lighting the most reliable way of determining the correct exposure is to use a flash exposure meter, but even the more simply ready-made units of this type tend to be quite expensive. However, the circuitry involved is less complex than one might think and a home constructed flash meter can be built at a comparatively low cost. This flash meter design covers a range of six or seven stops and is suitable for use with any normal electronic flashguns, including the variable power type. It is very simple to use and does not require any connection from the camera to the meter.

By Robert Penfold

★ Simple to construct. ★ Can be used with variable power electronic flashguns. ★ No connection to camera required. ★ Makes finding the correct exposure easy.

F·L·A·S·H M·E·T·E·R

Operating Principle

Metering flash obviously poses a more difficult problem than metering available light. Instead of a continuous light level it is necessary to measure a short pulse of light. Furthermore, it is not just the intensity of the light that determines the exposure, but the duration of the light pulse. In fact with variable power flashguns there is no significant difference in the intensity of the flash between full and minimum power; the power of the gun being varied by controlling the duration of the flash.

Figure 1 shows the block diagram for the flash meter project, and this helps to show the way in which the problem of measuring both flash intensity and duration are solved. The light detector circuit makes usè of an inexpensive phototransistor. This has a suitably fast response time plus reasonably good sensitivity. A diffuser is used over the phototransistor to give the unit a wide response angle despite the rather narrow response of the phototransistor. A voltage regulator gives a well stabilised supply to the photocell circuit so that variations in the battery voltage do not significantly affect the sensitivity of the unit. The output of the photocell circuit is capacitively coupled to the next stage of the unit. A DC coupling would not be satisfactory as it would result in the ambient light level activating the circuit. The AC coupling blocks any small DC component on the output from the photocell circuit, but efficiently couples the pulse caused by the flashgun through to the next stage. Variations in the ambient light level will result in a signal being coupled through to the next stage, which is a rectifier circuit. This uses silicon diodes, and the forward threshold voltage of these is high enough to block the small signals produced by changes in the ambient light level, but does not block the larger signals caused by the light pulses from the flashgun. This system relies on the light level from the flashgun being substantially higher than the ambient light level, but this should always be the case in practice as flash lighting would otherwise be unnecessary, and almost certainly unusable. There is actually an alternative way of doing things, where the output of the photocell circuit is only coupled through to the rest of the circuit when the flash contacts of the camera are closed. This method seems to have fallen from favour in recent years, and although it is supèrior in certain respects, it is less convenient in use as it requires connections from the camera to the flashgun.

The next stage of the unit is a Miller Integrator. This is perhaps not one of the best known circuit blocks, but is nevertheless a very useful type of circuit. Figure 2 shows the circuit for a Miller Integrator. Initially the input and output are both at earth potential. If a positive signal is applied at the input, this unbalances the two input voltages of the operational amplifier and sends the output negative. What actually happens is that Ca charges via Ra, and the output of

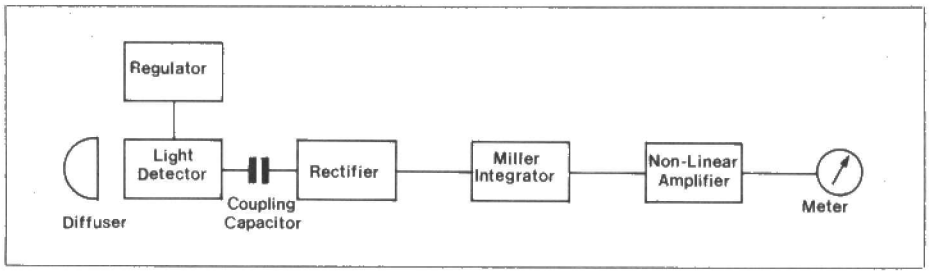


Figure 1. Flash Meter Block Diagram

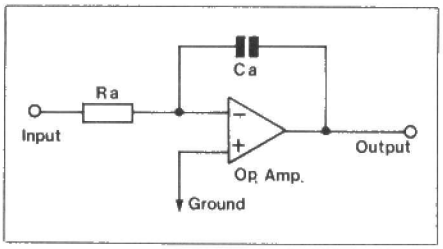


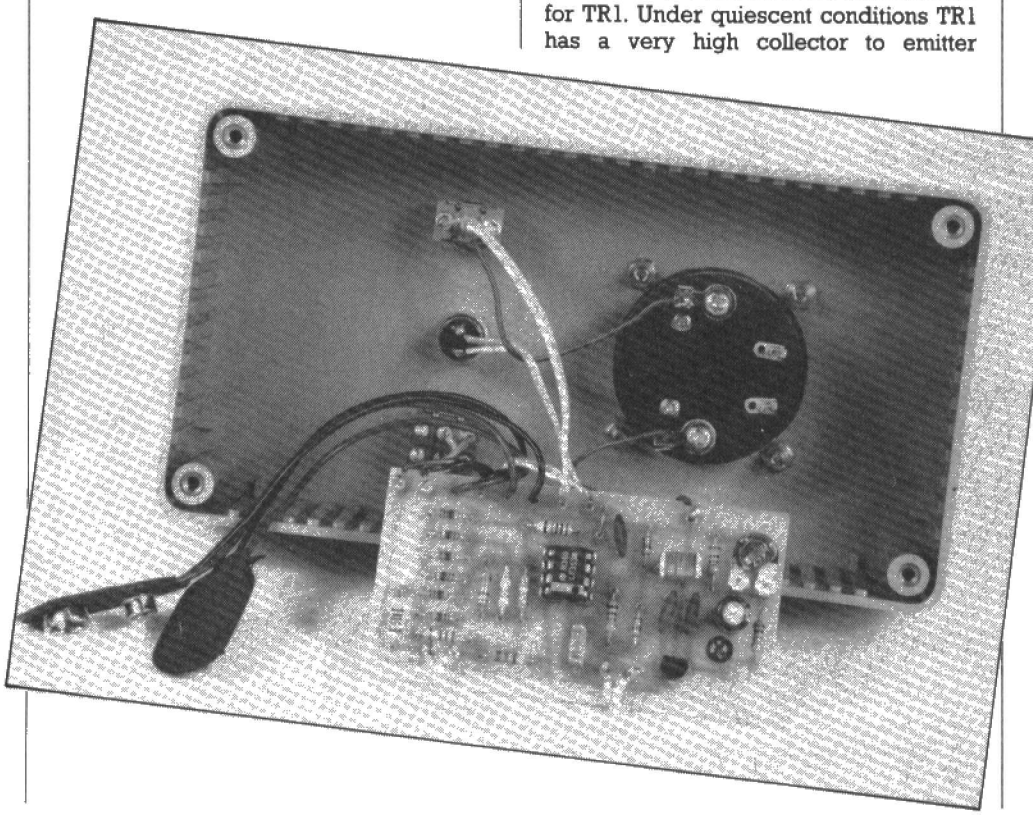
Figure 2. Miller Integrator Circuit

the operational amplifier goes negative by an amount equal to the charge voltage on Ca in order to keep the input voltages balanced. An interesting and useful property of this type of circuit is that the inverting input is maintained at earth potential, so that with a constant input voltage the charge current through Ra and into Ca remains constant. Ca therefore charges in linear fashion and not in the normal exponential manner so that the output voltage goes negative at a constant rate. This is ideal for our present purposes, since the output voltage is governed by both the amplitude and duration of the input pulse. A high input voltage gives a fast change in output voltage, and thus a large output voltage for a given pulse duration. A long pulse duration results in the output swinging negative for a relatively long time, and therefore produces a large output voltage. The unit accordingly gives accurate and consistent results regardless of whether the flashgun in use has a short but powerful output, or a relatively weak but long flash output.

The final stage of the unit is a non-linear amplifier which drives an ordinary moving coil panel meter. The output voltage from the Miller Integrator is non-linear, with the difference between F stops being large at the high end of the scale, and small at the low end. This is simply because the amount of light is halved each time the exposure is reduced by an F stop. In other words, one stop down from full scale deflection would be half scale deflection, two stops down would be one quarter of full scale deflection, and so on. This type of scaling makes it impossible to cover a wide exposure range with good accuracy. The non-linear amplifier has a level of gain that reduces as the input voltage is increased, and this spreads the calibration points out more evenly across the scale of the meter, giving better accuracy and making the unit much easier to use.

The Circuit

Figure 3 shows the full circuit diagram for the flash meter. IC1 is a small 5 volt monolithic regulator which is used to provide the stabilised supply for the photocell circuit. The latter utilizes the collector to emitter resistance of phototransistor TR1, and R1 is the load resistor for TR1. Under quiescent conditions TR1 has a very high collector to emitter



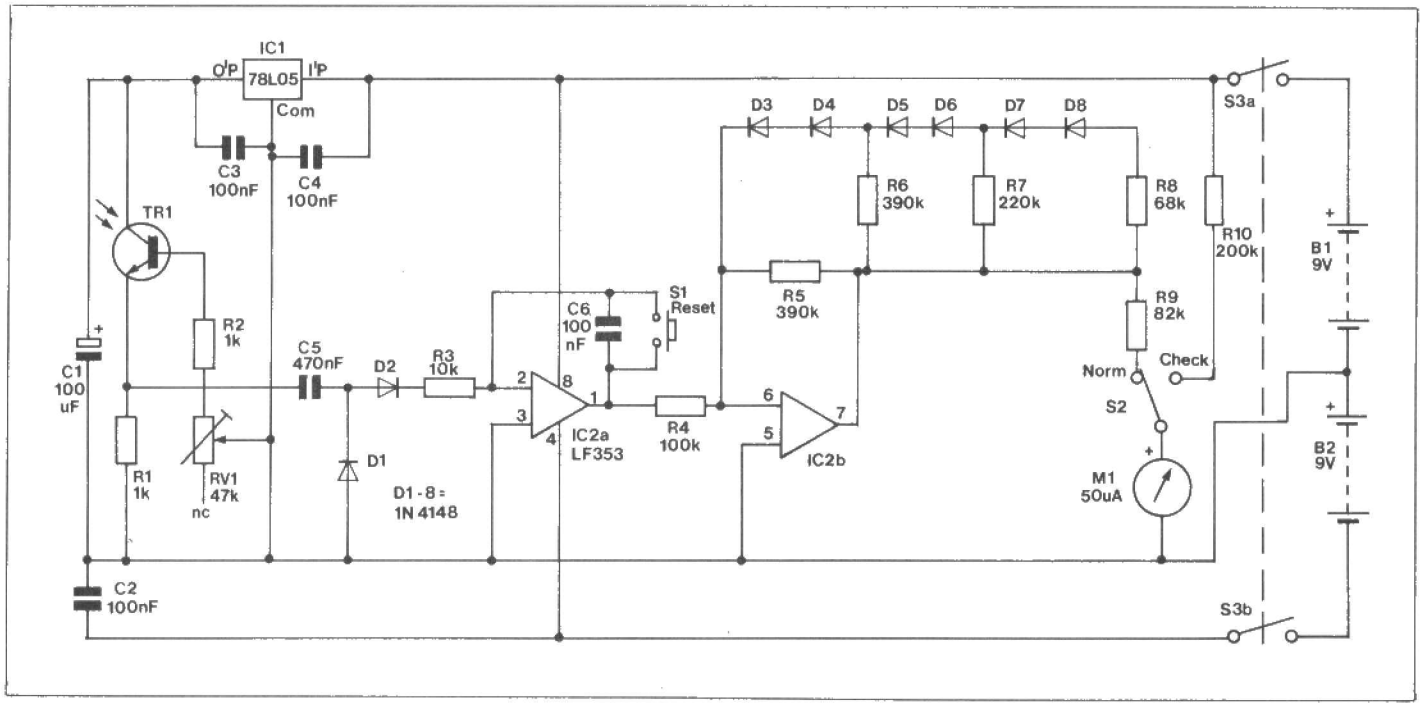


Figure 3. Circuit Diagram of Flash Meter

resistance, but this falls to a low level when TR1 is subjected to the high light level from the flashgun. This gives a positive pulse across R1, and provided TR1 is not driven into saturation the amplitude of the pulse is roughly proportional to the light level. R2 and RV1 reverse bias the base of TR1 and enable the sensitivity of the photocell circuit to be set at a suitable level.

C5 couples the output of the photocell circuit to a simple rectifier circuit using D1 and D2. The output of these is fed to the Miller Integrator based on IC2a. S1 can be used to discharge C6, and it therefore acts as the reset control. Obviously the charge on C6 will gradually leak away, but provided C6 is a good quality component and the specified ultra-high input impedance (JFET type) operational amplifier is used in the IC2 position, readings will be held accurately for a minute or more. This is obviously more than long enough to enable the meter to be read.

IC2b is used in the non-linear amplifier which is basically an ordinary operational amplifier inverting mode circuit. R4 and R5 are a negative feedback network which set the voltage gain of the circuit at 3.9 (390k divided by 100k = 3.9) with small input voltages. If the output goes positive by more than about 1 volt the first two diodes in the chain (D3 to D8) are biased into conduction, and R6 is shunted across R5 so that the gain of the circuit is reduced to only about half its previous level. Higher output voltages cause R7 and R8 to be switched into circuit as the other diodes in the chain are brought into conduction, giving the circuit a suitably non-linear transfer characteristic.

Meter M1 can either be switched to register the output voltage of the flash meter circuit, or it can be connected across the positive supply via R10. This resistor converts the meter to a simple 0 to 10 volt type so that the positive supply potential can be checked. A dual 9 volt supply is needed, and this is obtained from two small (PP3 or equivalent) batteries. Both batteries should be replaced when the positive supply voltage drops to about 7.5 volts. Note that the battery check facility only operates when the unit is switched on, but this is correct as it is the loaded supply voltage that should be checked. The current consumption of the circuit is approximately 7 milliamps from

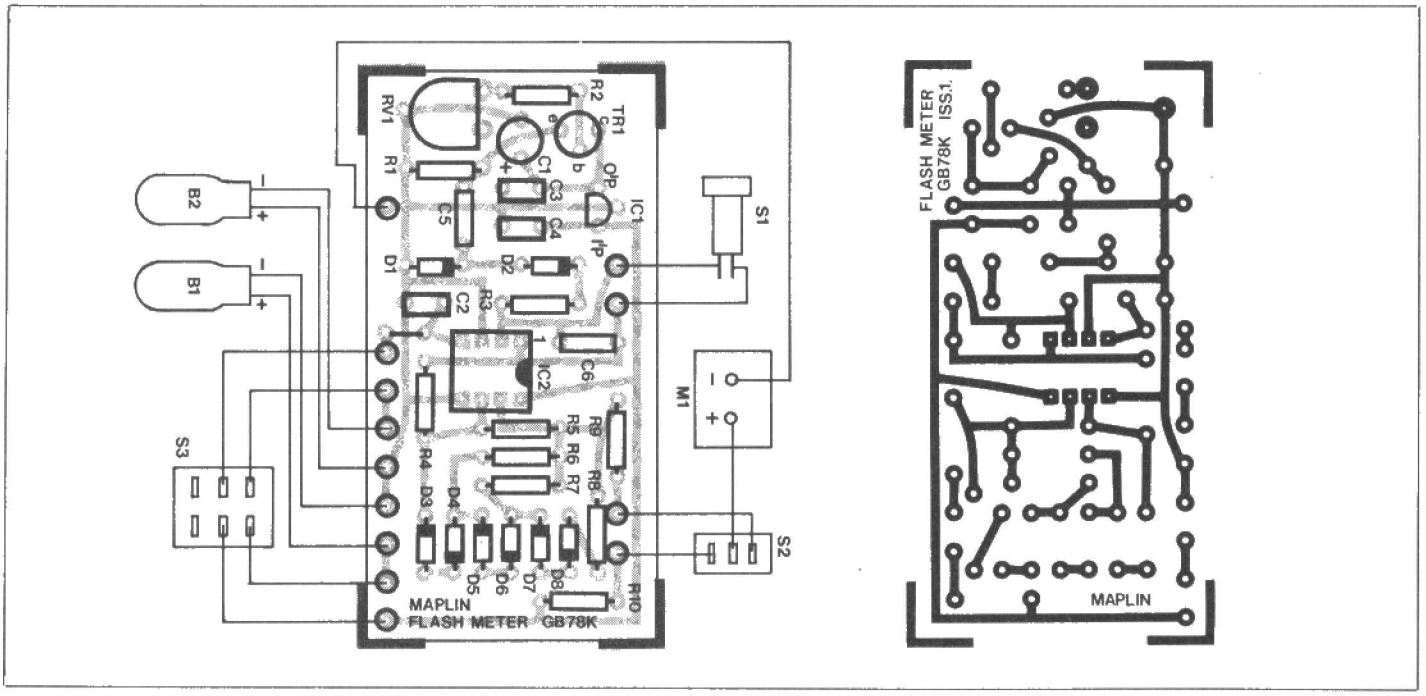


Figure 4. PCB Artwork and Layout

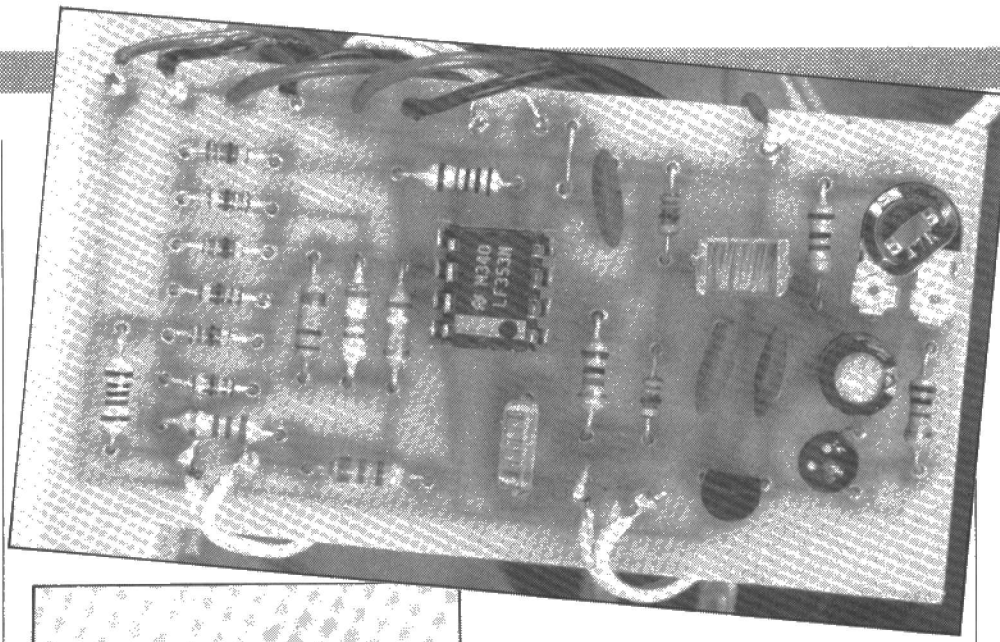
the positive supply and 4 milliamps from the negative supply.

Construction

All the small components are mounted on a printed circuit board, as detailed in Figure 4. Construction of the board does not present any real difficulties, but be careful to fit all the diodes on to the board with the correct polarity. Leave the leadout wires of TR1 at full length. Veropins are fitted to the board at the points where connections will eventually be made to the meter and switches. A plastic box having dimensions of 150 by 80 by 50 millimetres is used as the housing for this project, and this case has printed circuit guide rails which the circuit board is designed to fit. The case is used vertically, with the removable lid becoming the rear panel of the case. The printed circuit board fits into the second highest set of guide rails with the component side of the board facing upwards.

A hole about 10 millimetres in diameter is drilled in the top of the case to enable light to pass through to TR1. A diffuser of some kind must be fitted over this hole, and on the prototype the diffuser was made by carefully cutting a table tennis ball in half using a scalpel. This was then simply glued in place using a good quality general purpose adhesive. Ideally the diffuser would be somewhat smaller than a table tennis ball (say about 15 millimetres in diameter), and you might be able to improvise something better. Note though, that the diffuser must let a reasonable amount of light through to TR1 if the unit is to cover a useful exposure range. In fact a table tennis ball is fairly dense, and will result in the unit being fairly insensitive. This is perfectly alright if your main interest is something like close-up photography where high aperture values are needed, but something less dense would be better for general photographic work. Fine sandpaper can be used to slightly thin down the diffuser if necessary. Of course, the sensitivity of the circuit can be adjusted over a fairly wide range, but the adjustment range is inadequate to cope with a diffuser that is much too dense or too thin.

The meter and three switches are mounted at any convenient places on the front panel. The meter needs a main cutout 38 millimetres in diameter. This can be cut using a fretsaw or a miniature round file, or an alternative is to drill a ring of small holes (about 3 millimetres in diameter) just inside the perimeter of the required cutout, spacing the holes as close together as possible. A sharp knife is then used to join the holes, after which a large half-round file is used to tidy up the cutout and enlarge it to the required size. The four 3.3 millimetre diameter mounting holes are then drilled, and the meter can be utilized as a sort of template to assist with the marking of the positions of these holes on the front panel. To complete the unit the small amount of point to point wiring is added. A piece of foam material can be used to keep the batteries in place inside the case.



Adjustment

The basic method of calibrating the unit is to first set it up on a table in an average size room and not within about one metre of any walls. Start with the flashgun 0.5 metres away from the flash meter and take a reading. Remember that reset switch S1 should always be used to zero the meter before a reading is taken. What we require here is a reading at something in the region of the full scale value, and if a suitable reading is not obtained try repeating this procedure with RV1 at different settings until a suitable reading is obtained. If you are using a powerful flashgun it might be necessary to use it at half or quarter power. Then move the flashgun to distances of 0.7 metres, 1 metre, 1.41 metres, 2 metres, 2.82 metres, and 4 metres from the flash meter, being careful to accurately measure the distances and noting the readings at each distance.

Depending on whether or not a reading is obtained at the top maximum distance, this gives six or seven readings at one stop intervals. Ideally the front of the meter should be removed and these points should be carefully marked onto the scale plate, but it is not essential to do this. One way of using the meter is to make up a chart of the type shown in Table 1.

ASA	1	2	3	4	5	6
25	5.6	8	11	16	22	32
50	8	11	16	22	32	45
100	11	16	22	32	45	64
200	16	22	32	45	64	90
400	22	32	45	64	90	

Table 1.

This shows the aperture required for given film speeds and exposure values read from the meter, but the figures in the table are only intended as a guide. To find the correct values it is necessary to consult the exposure calculator of the flashgun used to calibrate the unit. It is advisable to take some test shots using the meter to determine the exposure, and then examine the results. Obviously the 'typical' surroundings used when calibrating the unit might not produce completely accurate results, and the only way to test this and make any necessary adjustments to the calibration is to try a practical test.

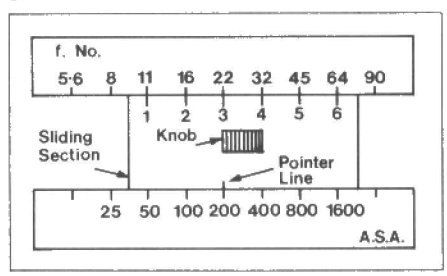


Figure 5. A Sliding Exposure Calculator

The unit will be more convenient in use if the exposure chart is replaced by some kind of exposure calculator. Figure 5 shows the basic set-up for a sliding exposure calculator. The divisions on all three scales are at one stop intervals, and the same spacing should therefore be used on all three scales. The idea is to set the sliding pointer to the appropriate film speed, and then the corresponding aperture for each exposure value can be read from the upper scale. Again, the values shown are only intended as examples, and might need to be altered to suit the particular diffuser and setting for RV1 that you have used. If exposure values are

not marked on the scale of the meter, in both the exposure chart and on the calculator the exposure values would have to be replaced with the relevant meter readings. This would be much slower and more difficult in use though.

The meter should work well with variable power flashguns, apart from the types which cover a very wide power range. The problem with these is that the flash duration at the very low output power settings is extremely brief (usually something in the region of 1/15000th second). The response speed of the phototransistor may be inadequate to cope with this accurately, and of more importance, there is the problem that the light output from the flashgun is purposely made too high at very low power settings to compensate for the loss of film sensitivity that occurs at very short exposure times. This is obviously a factor that the flash meter does not take into account, and it would consequently give an accurate but misleading reading. When using a variable power flashgun with the unit it is therefore advisable to only use power levels of about 1/8th power or more so that very short flash durations are avoided.

PARTS LIST FOR FLASH METER

RESISTORS: All 0.4W 1% Metal Film			
R1,2	1k	2	(M1K)
R3	10k	1	(M10K)
R4	100k	1	(M100K)
R5,6	390k	2	(M390K)
R7	220k	1	(M220K)
R8	68k	1	(M68K)
R9	82k	1	(M82K)
R10	200k	1	(M200K)
RV1	47k Hor S-Min Preset	1	(WR60Q)
CAPACITORS			
C1	100µF 10V PC Electrolytic	1	(FF10L)
C2,3,4	100nF Minidisc	3	(YR75S)
C5	470nF Polycarbonate	1	(WW49D)
C6	100nF Polycarbonate	1	(WW41U)
SEMICONDUCTORS			
TR1	Infra-Red Sensor	1	(YY66W)
IC1	µA78L05AWC	1	(QL26D)
IC2	LF353	1	(WQ31J)
D1-8	1N4148	8	(QL80B)

MISCELLANEOUS			
S1	Push Switch	1	(FH59P)
S2	Sub-Min Toggle J	1	(FF70M)
S3	Sub-Min Toggle E	1	(FH04E)
M1	2in. Pan Meter 50µA	1	(RW91Y)
	Printed Circuit Board	1	(GB78K)
	PP3 Clip	2	(HF28F)
	DIL Socket 8-pin	1	(BL17T)
	Veropin 2145	1 pkt	(FL24B)
	Hook-up Wire	1 pkt	(BL00A)
OPTIONAL			
ABS Box 2005	1		(LH61)
	Diffuser – see text		

A kit is available to build this project (not including Optional items).
Order As LK58N (Flash Meter Kit) Price £13.95

The Flash Meter PCB is available separately.
Order As GB78K (Flash Meter PCB) Price £1.75

MAPLIN'S TOP TWENTY KITS

THIS MONTH	LAST MONTH		DESCRIPTION OF KIT	ORDER CODE	KIT PRICE	DETAILS IN PROJECT BOOK
1.	(1)	♦♦	75W Mosfet Amplifier	LW51F	£15.95	Best of E&MM
2.	(–)	♦	VIC20 Talkback	LK00A	£22.95	6 XA06G
3.	(3)	♦♦	Car Burglar Alarm	LW78K	£7.49	4 XA04E
4.	(4)	♦♦	Partylite	LW93B	£10.95	Best of E&MM
5.	(2)	♦	Modem	LW99H	£49.95	5 XA05F
	Case also available: YK62S Price £10.95.					
6.	(6)	♦♦	8W Amplifier	LW36P	£4.45	Catalogue
7.	(11)	♦	Ultrasonic Intruder Detctor	LW83E	£10.95	4 XA04E
8.	(–)	♦	Light Pen	LK51F	£10.95	12 XA12N
9.	(9)	♦♦	Syntom Drum Synthesiser	LW86T	£12.95	Best of E&MM
10.	(12)	♦	Logic Probe	LK13P	£10.95	8 XA08J
11.	(14)	♦	Harmony Generator	LW91Y	£17.95	Best of E&MM
12.	(13)	♦	ZX81 I/O Port	LW76H	£10.49	4 XA04E
13.	(8)	♦	Cautious Ni-Cad Charger	LK50E	£19.95	11 XA11M
14.	(16)	♦	Burglar Alarm	LW57M	£49.95	2 XA02C
15.	(10)	♦	Spectrum RS232 I/F	LK21X	£19.95	8 XA08J
16.	(5)	♦	Spectrum Easyload	LK39N	£9.95	10 XA10L
17.	(–)	♦	Computadrum	LK52G	£9.95	12 XA12N
18.	(–)	♦	Dragon 32 I/O Port	LK18U	£15.95	8 XA08J
19.	(–)	♦	50W Amplifier	LW35Q	£15.95	Catalogue
20.	(–)	♦	Xenon Tube Driver	LK46A	£11.75	11 XA11M

Over 80 other kits also available. All kits supplied with instructions.
The descriptions above are necessarily short. Please ensure you know exactly what the kit is and what it comprises before ordering, by checking the appropriate Project Book mentioned in the list above.

SALES ASSISTANT
Required

Our Westcliff shop has a vacancy for a smart sales person. A knowledge of electronics is useful but component recognition is essential. We offer excellent opportunities for advancement with good wages and working conditions. Please contact Mr Tony Search for interview on

0702-554000

or write giving full C.V. to Maplin Electronic Supplies Ltd, 284 London Road, Westcliff-on-Sea, Essex.

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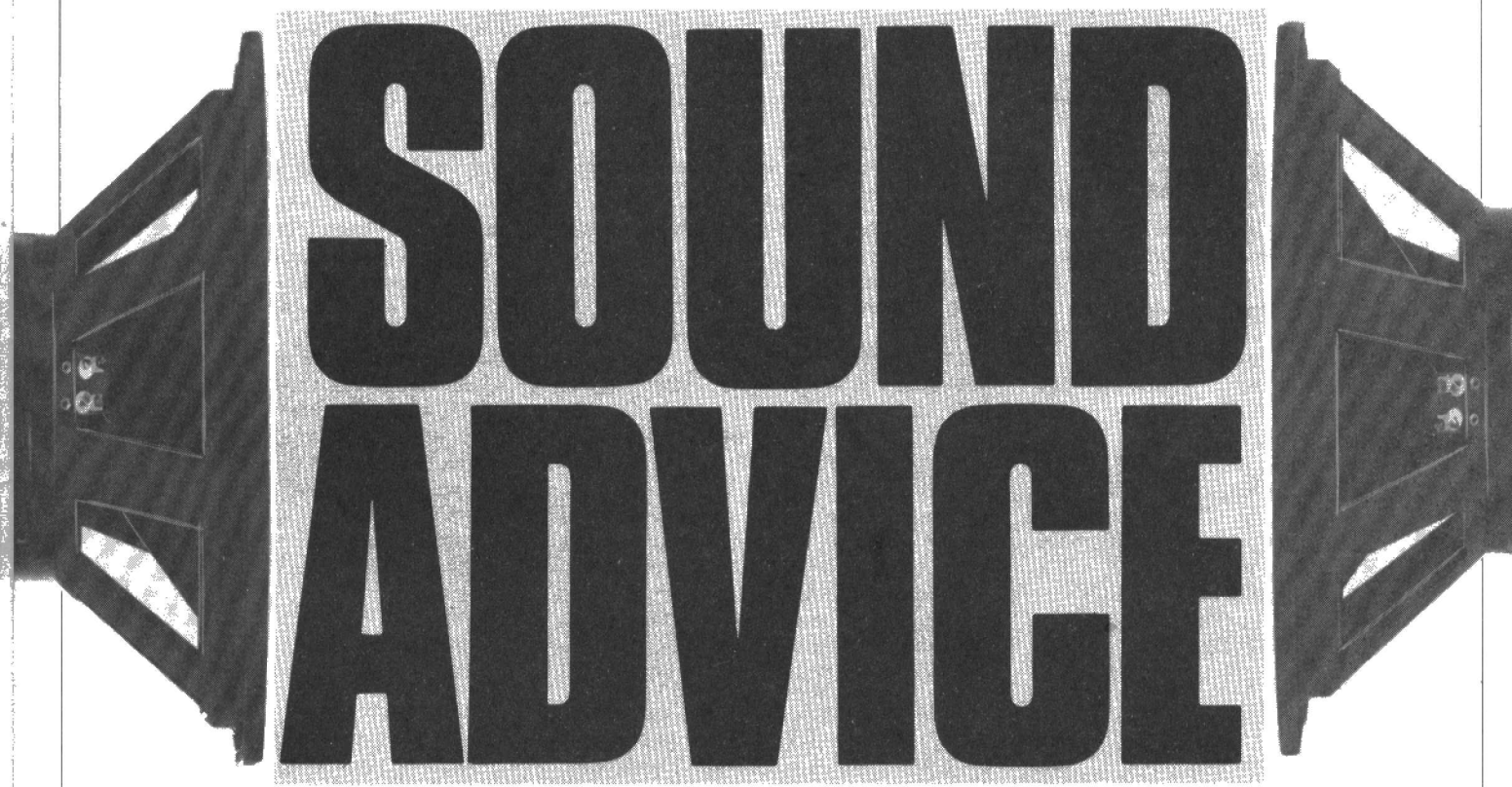


Improving Your Sound with Replacement Speakers

by J.D. Peyton

Introduction

How often have you wondered whether you should dig deep into those hard-earned savings and lash out on the price of a complete new speaker system or combo-amplifier? And to what purpose? Usually in order to improve on what you have already, to obtain a better sound quality - and lots more of it.

To try to achieve this by spending several hundred pounds on completely new equipment is not only (and obviously) a very expensive way of doing it, but is also fraught with pit-falls. To be certain that system 'A' is better than system 'B', assuming that the latter is the one you already own, you need to be able to make an instantaneous detailed comparison of the two systems, under identical working conditions.

At best this is an arduous undertaking, and for the average person usually impossible. To try to assess sound quality and comparative loudness from printed technical specifications frequently leads to disappointment, particularly if too much importance is placed on that most misleading of criteria, Nominal Power Rating. Amplifier power ratings are almost always given as a maximum at a point beyond which serious distortion occurs, and there is no indication of the 'flat-out' power available (all control knobs fully clockwise).

In other words one brand of 50W amplifier may truly deliver 50 watts maximum output, whereas another model might capably produce 75 watts. This writer has knowledge of one model in particular which produces 97.5 watts! And yet all these come under a nominal 50 watts output classification.

Since we are here considering both combination systems and seperates under the same heading, the foregoing remarks assume that all amplifiers are being driven into their appropiately proper matched speaker load (or correct speaker impedance). Furthermore, the printed specifications of combination sound systems, whatever the type, *never* make reference to one of the two most significant, if not vital, factors which determine sound output and loudness - that of speaker efficiency. At all times, but particularly when attempting to assess the relative merits of systems with similar nominal power ratings, the conversion efficiency, or sensitivity, of the speakers in question is of prime importance, but is never incorporated into the written specifications. The fundamentals of this very problem were set out in an excellent leading article written by the Technical Editor of 'Music UK', which was published in issue 13 of that magazine. To quote his very words – "...Haven't you ever found yourself confronted with two ostensibly identically rated combo's and noticed one sounding maybe twice as loud as the other? It happens to us all the time ... accordingly a rating in watts can become relatively meaningless when the actual sound pressure levels of a combo are measured ... one thing we've found is that substituting the original speakers with more up-market types can produce a tremendous difference both to the perceived volume of the combo amp's in question, and also the quality of the sound itself."

By far the most cost effective way of improving both the volume and the quality of your sound is by upgrading your speaker drive units. The Americans call it 're-speakering'. In the USA, the replacement speaker market has become THE major vehicle for speaker sales, well over 50% of all speakers being sold for the express purpose of improving the performance of existing equipment.

Speaker Efficiency Explained

What is sometimes called the sensitivity, conversion efficiency, or just plain efficiency of a speaker, is determined by a whole host of factors concerning the materials used and the technical design of the driver unit. It is not the purpose of this article to provide an in-depth description of speaker design technology, so it will suffice to say that, although there are certain specialised models produced in the design of which efficiency plays second fiddle to other considerations, the vast majority of speakers are intended by their designers to produce as much sound, or loudness, as possible within the cost limitations for a particular example. Some manufacturers are much more successful at achieving this high efficiency level than others; if this were not the case this article would scarcely be necessary!

The unit measure used to quantify the loudness of sound is called the Decibel (usually abbreviated to dB). Standing alone the decibel is meaningless for most practical purposes, however, of great significance is the relationship, or difference, between one decibel measurement and another, since the decibel applied to loudspeaker technology is a relative measurement used for comparing the sound output (or Sound

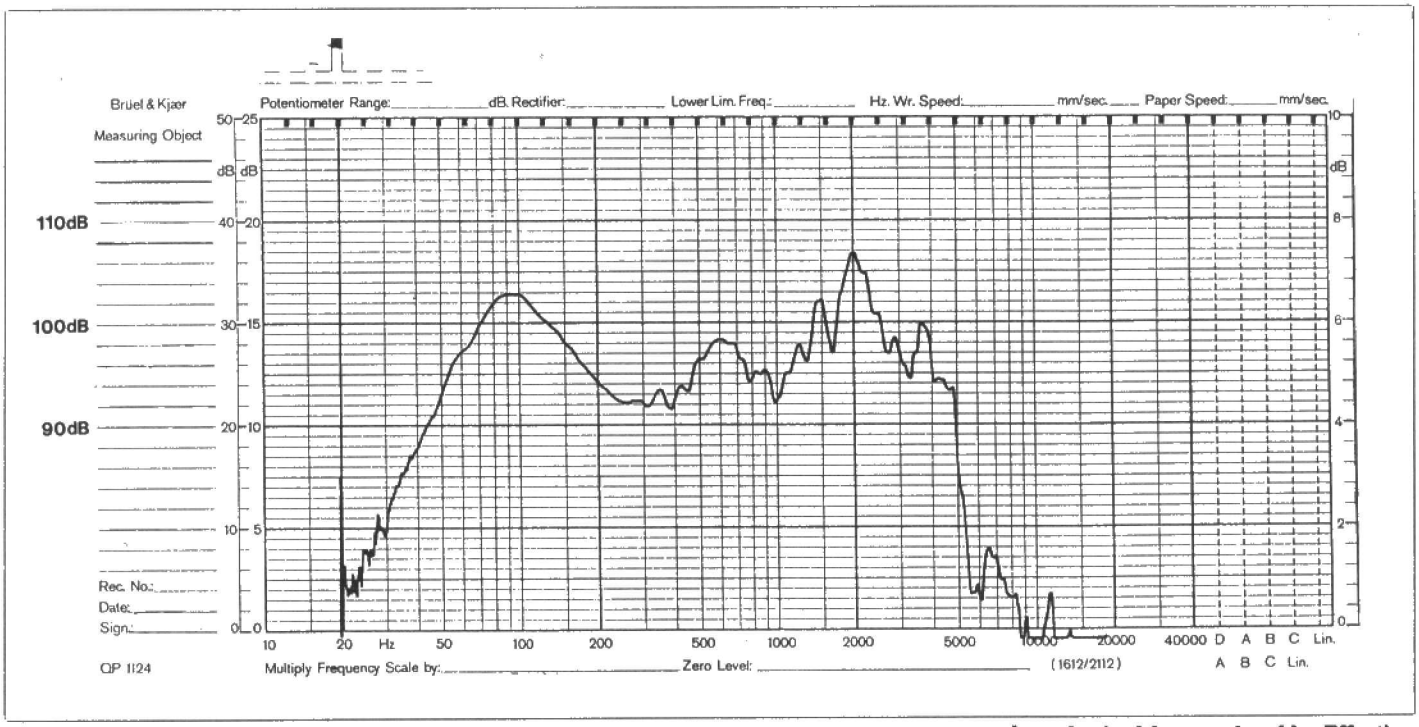


Figure 1. Frequency response curve of a typical 12" disco speaker with suppressed mid-range and emphasised bass and treble. Effective frequency response 50Hz – 5kHz. Average sound pressure level 98dB

Pressure Level - SPL) of one loudspeaker against another, and the crucial point here is that a *difference* of 3dB corresponds to a factor of 2 - times 2 (double) if greater than, or divided by 2 (half) if less, when comparing the sound output of a loudspeaker against a reference. For example, if speaker 'A' produces a sound pressure level of say 95dB, and speaker 'B' produces 98dB, then speaker 'B' is making twice as much sound as speaker 'A'! Similarly, speaker 'C' at 101dB is only half as loud as speaker 'D' which is producing 104dB (Fig.1-3)

Clearly, to enable an accurate comparison to be made between loudspeakers, it is essential that they are all measured and specified under identical test conditions, and this is almost always the case, certainly in the western world. Standard procedures require the measuring microphone to be positioned along the centre axis of the loudspeaker's cone, at a distance of exactly one metre, while the sound pressure level is measured as the loudspeaker is fed with a constant input of 1 watt, 'swept' over the full audio frequency band.

This produces a response curve, tracing a graph on a continuous paper chart recorder, showing the relative sound output levels at all frequencies. These are then averaged to produce the mean output level or SPL. The graph paper is marked in decibel steps above a zero starting point, making the assessment of a loudspeakers performance both simple and accurate.

A word of warning at this point – there are a few speaker manufacturers, mainly located in the Far East, who take their measurements with the microphone closer to the speaker under test than 1 metre, often at only ½ metre distance. This will produce a falsely high SPL figure, if read as a direct comparison to the western standard. Always check with the manufacturer's specification sheets that SPL figures are given as 1 watt – 1 metre, and beware if this is not so, or not stated.

So far, then, we have seen that a dramatic increase in SPL is possible by 're-speakering', or replacing the drive

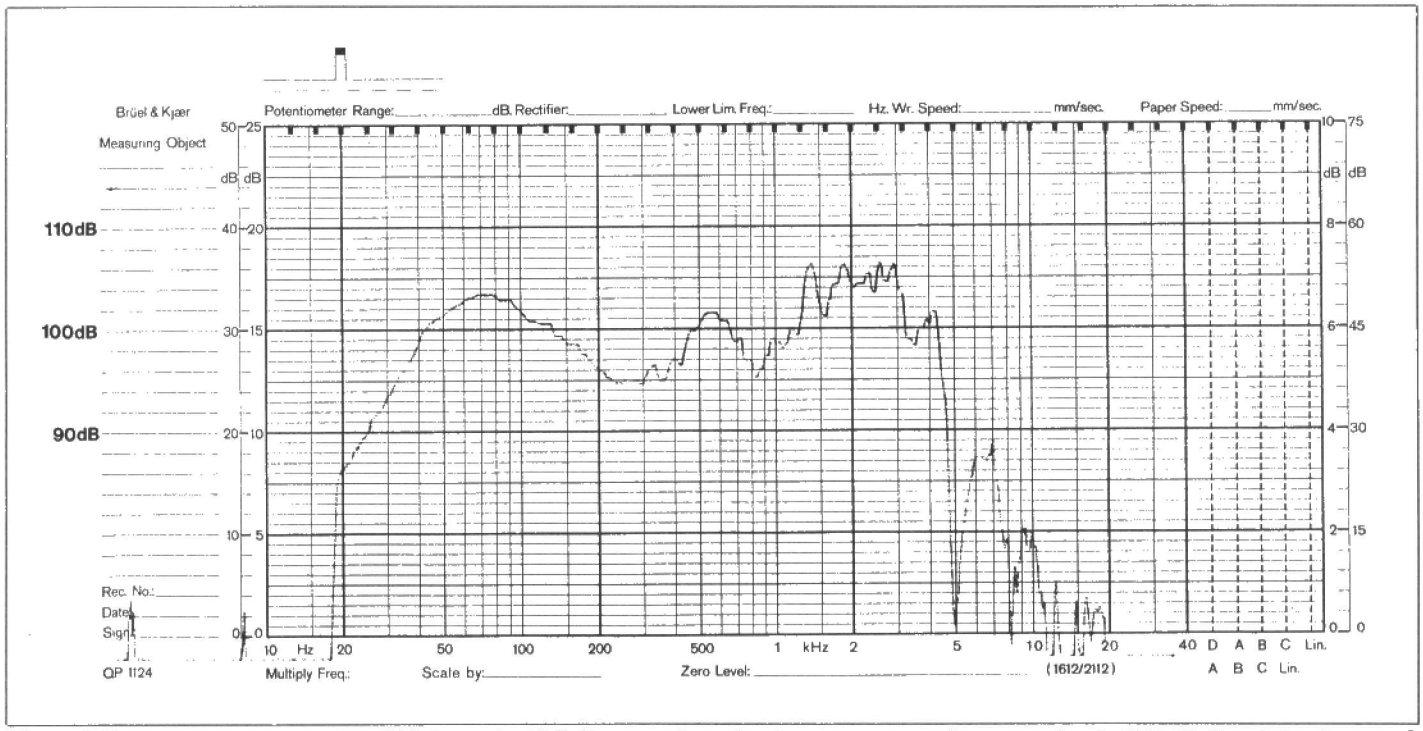


Figure 2. Frequency response curve of higher output 12" disco speaker, showing average sound pressure level of 101dB, thus twice the sound output of speaker in Fig. 1

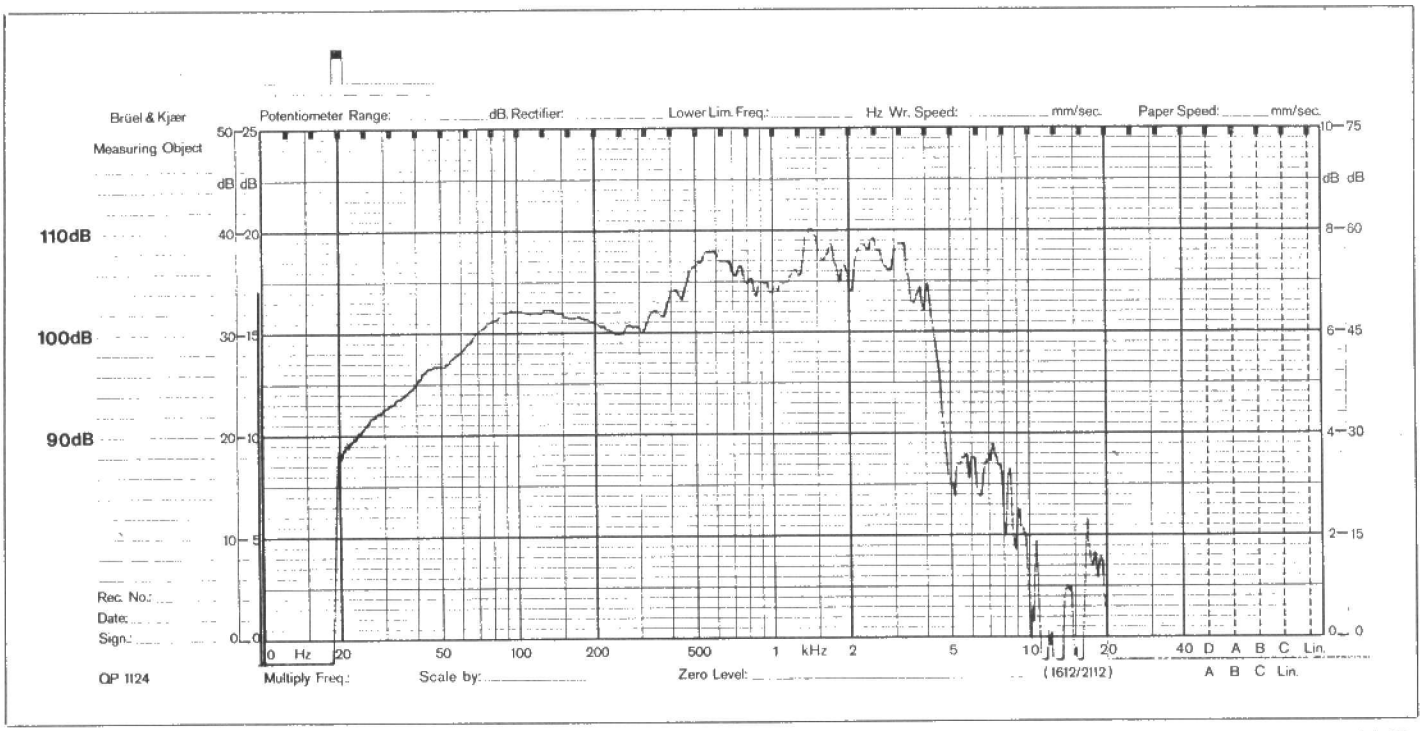


Figure 3. Frequency response curve of extra high output 12" guitar speaker (Fane Studio 12G), showing average sound pressure level of 104 dB, thus twice the sound output of speaker in Fig. 2 and four times the output of speaker in Fig. 1. Note that in the range 500Hz – 3.5kHz, the lead guitar's most effective area, this speaker is putting out an incredible 107 dB, eight times the output of speaker in Fig. 1!

units with higher efficiency ones. But there is another factor to be taken into account, before we discuss the choosing of a suitable replacement speaker – that of how efficient are the existing (original) speakers, and to what extent is it possible for you to determine how many dB's difference you should be looking for, to obtain a suitable improvement.

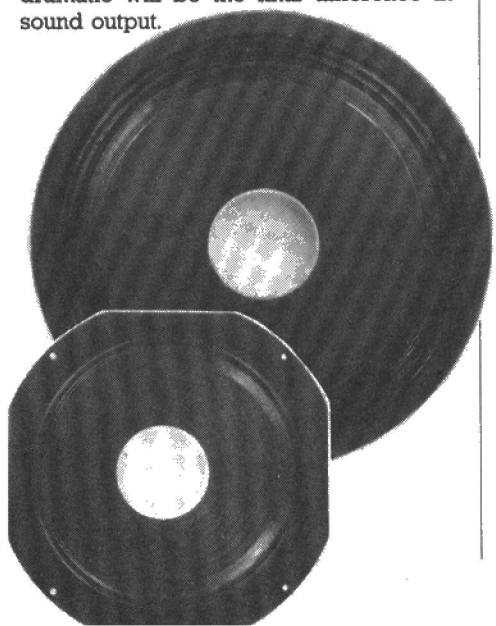
If you are in the habit of putting your sound equipment together yourself, you will obviously know which make and model of speaker you have originally used, and it is a simple matter to refer to the relevant manufacturer's literature (assuming you remembered to keep it). Alternatively you can make a direct enquiry with the manufacturer to determine the conversion efficiency of the model in question. Suppose it were, say, 95dB, you then know that you should seek a unit giving at least 98dB to obtain a significant increase in sound output.

Much more commonly, though, it will be a standard, commercially fitted product which is the subject of 're-speakering', and so determining the efficiency of this originally fitted item is not always so straightforward.

Speakers fitted by equipment manufacturers can be broadly divided into two catagories – standard, off-the-shelf models, or specially-customised (or OEM) models. A standard model will have been selected for ease of availability, cheapness, or because, quite by chance, it happens to be the most suitable for the application. Unless it is one of the few very expensive and exotic types, it will almost certainly be a suitable candidate for up-grading.

On the other hand, an OEM model will have been carefully 'tailored' and customised by the manufacturer to match the characteristics of the amplifier it relates to or to provide a specific quality and level of sound output. Many of these are already high output types and special care is needed when trying to upgrade one of these. Even so, nearly all equipment manufacturers have to balance cost and competitiveness against the ultimate in performance, and so it should be possible in many cases to achieve some degree of improvement by careful 're-speakering'.

OEM speakers usually carry a specification number, but never a model type identifier. Often they are labelled with the equipment name rather than the actual speaker manufacturer, implying that they are rather special and exclusive to that product. Enquiries to determine SPL must of necessity be directed through the equipment manufacturer. If all else fails it is a useful 'yardstick' to assume that a replacement speaker with an efficiency of 100dB is likely to provide some sort of improvement, and that the higher one can achieve over 100dB, then the more dramatic will be the final difference in sound output.



Choosing a Replacement Speaker

So far, we have considered the increase in sound output and quality which can be obtained at relatively modest cost, by following the popular American custom of re-speakering. But there are a number of other factors which must be considered when choosing a replacement speaker. Will it fit where the old one fitted? Is it well made and durable? Is the speaker impedance a correct match to your amplifier? Is it designed to do the job for which you are intending to use it, and does it have a sufficient power rating? Is it covered by a suitable guarantee? Let us consider these remaining important factors one by one.

Fitting

There are two commonly-used methods of fitting speakers: front-mounting or rear-mounting. Front-mounted speakers are often accompanied by a protective steel grille, which is either separate from the speaker or permanently attached to it, as is the case with some models from Fane and McKenzie. In either case, the speaker is normally secured either by means of special front-mounting clamps, or with bolts directly through the speaker fixing holes and into T-nuts secured to the inner surface of the cabinet. If the former is the case, the only fitting consideration is the diameter of the speaker cut-out in the cabinet. This should be measured and checked with speaker manufacturers literature in respect of baffle hole requirements since there can be a variation in this requirement between different models.

With the latter fixing method, and also in the case of rear-mounting speakers, the location of the fixing holes in the speaker chassis is of crucial importance.

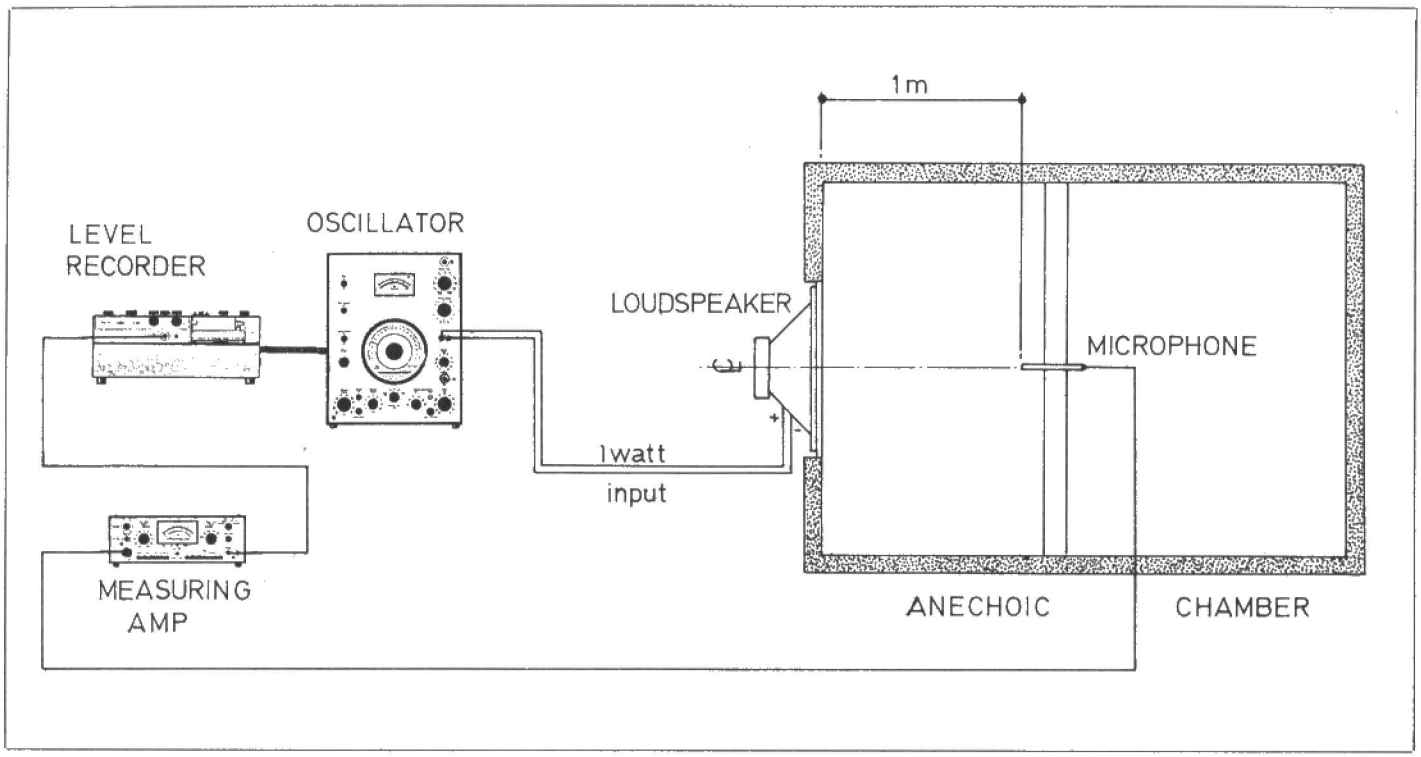


Figure 4. Diagrammatic layout for frequency response and sound pressure level measurement

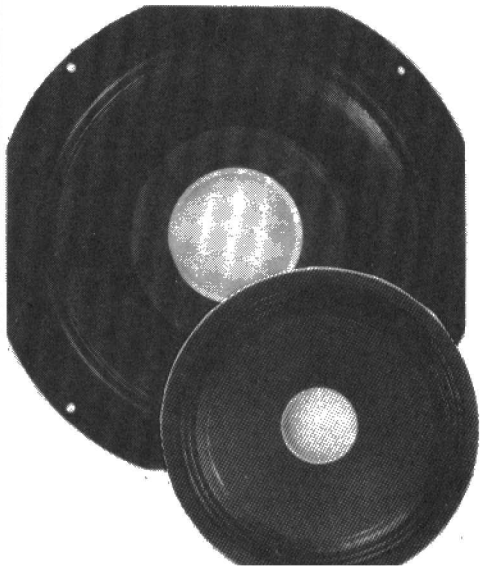
The majority of speaker manufacturers incorporate the same common fixing dimensions, so that one will readily replace another, but certain models, including in particular, some of the more expensive American speakers, have their fixing holes situated on a different diameter (PCD). As far as we are aware, only one maker – Fane, with their 12" and 15" diecast chassis – caters for both sets of dimensions by including alternative sets of fixing holes in the same chassis. (The new range from Maplin also makes this provision).

Under-size baffle holes are not too much of a problem, since they can be enlarged with a wood rasp, but if the fixing holes or bolts are incorrectly sited for your new speaker, they will have to be re-located using a hacksaw and a new set of fixing bolts.

Will it be Durable?

One way to get a general idea of durability is to look around and see which makes of speaker are fitted by leading equipment producers like Vox, Haney, Custom Sound etc. Such manufacturers do not repeatedly use speakers which have not proved totally reliable, since to do so could damage their reputations. But because, as mentioned earlier, some of those producers 'own-label' their speakers, it is not always easy to find out who is manufacturing them, and close examination of prospective replacement speakers is always advisable. First, consider the chassis. Diecast types are normally considered to be the best, and are employed for most up-market models, but there is nothing whatsoever wrong with pressed steel chassis providing that they are suitably designed and finished. In particular, study the finish, which should include a coating of protective stove-enamel paint over the plated surface. Who has not seen those piles of defective rusting, unpainted speakers behind the local repair shop? Plated steel looks fine and bright when it is new, but the atmosphere can play havoc with it after even quite a short time. How long do those unpainted steel areas of a car body last, for example? Not a perfect parallel, perhaps, but a speaker has to be able to withstand a very wide variation in temperature and humidity, and a layer of tough stove-enamel certainly goes a long way in extending it's lifespan.

Another external point to note is magnet protection. Ceramic magnet material is really quite fragile and can chip or crack if subjected to knocks. For this reason, some speaker manufacturers fit a protective cap over the magnet, or some form of ring or moulding around the vulnerable magnet edges. This is evidence of care and attention to detail during the design stage which will probably reflect upon the internal design structure as well, but the absence of such magnet protection will not affect speaker performance providing that damage to the magnet itself is avoided.



Internally, a good high-temperature voice-coil is an essential, to cope with modern amplifiers and extended high power usage. High temperature coils are commonly based upon a tube or former of aluminium, which is a durable material but has certain restrictions in respect of performance. Certain types of plastic former have also been used with varying results. Undoubtedly, one of the best materials for high power coils is glass-fibre, which has all the advantages but only one drawback – cost. A glass-fibre coil requires special high-precision techniques for its manufacture and is therefore both time-consuming and relatively expensive to produce. Thus, few speaker makers use it, although in practical terms they know of no better material. At the other extreme, it is best to disregard any speaker fitted with a paper-laced coil. These can suffer from all sorts of problems and usually have a very short working life.

Under this heading of durability, it is also pertinent to deal with the subject of guarantees. If a speaker fails during its guarantee period for some reason other than misuse, the chances are that it will be due to some fault in materials or construction, and that the speaker manufacturer will ultimately have to foot the bill for replacement or repair. If a product has a track record of unreliability or of a short working life, the manufacturer will naturally escape as much liability as possible by offering the shortest warranty he can get away with. Conversely, if a product has proved to be durable and reliable, its manufacturer can afford to offer a longer guarantee. The most common guarantee period is 2 years, although one manufacturer at least offers 5 years, and one English manufacturer provides an incredible lifetime guarantee, which by definition is unbeatable!

Doubling your sound output is no use if that super output is only going to last 5 minutes! It has to stand up under all playing conditions, and to last – hopefully – a lifetime.

Impedance Matching

The new speaker must be a correct impedance match to whatever amplifier it will be used with; it must have the correct number of OHMS! 8 ohms and 16 ohms are the most common, but be sure to get it right. If you fit a 16 ohm speaker where the amplifier needs 8 ohms, the sound output will be reduced. Conversely, using an 8 ohm speaker where a 16 ohm one is required can cause amplifier damage. All speakers should be marked with impedance, but if your old one should carry no marking, any electrical specialist should be able to measure it for you, using a special meter.

Is it Designed for the Job?

Some speakers are designated 'General Purpose', which means that they are designed to withstand any kind of normal usage and to give decent results under all conditions, whereas others are designed to do a specific job to the exclusion of all others, and to do it really well. (See figs 2 and 3 for example). There are outstanding models in both categories, depending upon whether you need the speaker for, say, a lead guitar combo or for general music reproduction together with periodic vocals or guitar playing. There is a huge variety of choice in both categories, but when deciding to look for top performing replacement speakers, the field can be considerably reduced before you start by deciding whether you need a specialist or a general purpose model.

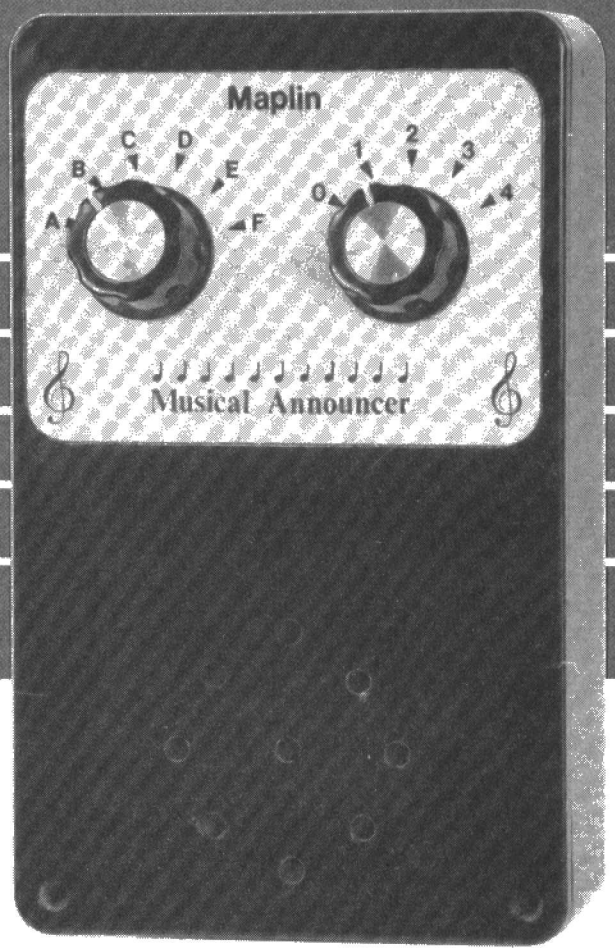
Conclusion

Having read this far, you will now be in possession of the basic criteria required for increasing the output level and quality of your sound at minimum cost, by respeakering; and you will know how to go about selecting a suitable replacement speaker without risk of disappointing results and wasted money. Space precludes mention of every available brand of speaker, but here are a few pointers to set you in the right direction. If you have money to burn and price is no object, you can consider the highly reputable offerings from JBL, Gauss or Electronica, all from the USA. Most of these feature cast chassis, magnet protection and a high general level of finish. Many use aluminium based coil formers. Sound output levels are usually on the right side of 99dB, but no higher than many British-made speakers. Be extra careful about fitting dimensions, and remember that a surprisingly high proportion of the cost of these speakers is represented by import duty and shipping costs from the USA, plus the importers profits. Spare parts

costs are usually horrendous. Good speakers certainly, but at two or three times the price of a British equivalent, which largely defeats the object of respeakering as opposed to buying a whole new equipment. Coming nearer home and considerably down in price the Celestion Company, which is well-reputed in the Hi Fi field, produces general purpose speakers, some early models of which (the ones with metal magnets and covers) were used to good effect by rock guitarists of the early 60's. The modern range includes some useful guitar speakers, but Celestion no longer provide any magnet protection and their steel chassis are not stove-enamelled. Fane Acoustics have a massive range, including both diecast and steel framed models, and feature both magnet protection and stove-enamelling. Sound pressure levels are mostly upwards of 100dB, including one 12" model producing an incredible 105dB! They have both general purpose models, and specialised up-market models produced by their professional division. Goodmans speakers are rather harder to find than they used to be, perhaps because that company has been concentrating heavily in the areas of Hi Fi and radio and TV speakers in recent times. Of the younger companies, ATC produce heavy-duty models, mainly featuring cast chassis',whose performance characteristics, lean heavily towards the PA and studio field. In particular, their special bass speakers, though not unduly loud, are well worth exploring for stage systems. HH Acoustics has recently been through troubled times and a change of ownership. Their professional models were good value for money, but be assured of the future of spare parts and servicing if you come across them. McKenzie speakers have featured unduly in the disco field and some are of useful sensitivity; but this company has been known to use paper-based voice-coils; and many McKenzie models have no edge protection for the magnet ring.

An exciting newcomer to the speaker field is the Maplin company, which has announced an exclusive and completely new range of high performance power speakers, made to their own specification by one of Europe's leading professional design specialists. All design parameters and specifications look to be exactly right for a most exciting new option in speaker up-grading. Bearing in mind the obvious high quality, prices too, seem most attractive, and anyone looking for high output sound at sensible cost should certainly investigate these exclusive new speakers.

Musical Announcer



by Dave Goodman

- ★ **28 Musical Effects of Tunes and Chimes**
- ★ **Variable Envelope for Piano to Organ Type Sounds**
- ★ **Three Control Switch Inputs**
- ★ **Can be Powered from 4 x 1.5V 'D' Cells or 6/12V DC PSU**
- ★ **Automatic Switch Off at end of Tune for Power Saving**
- ★ **No Special Setting Up or Musical Knowledge Required**

The Maplin Musical Announcer is a ROM based music synthesiser with twenty-eight pre-programmed tunes, selected by two rotary switches. A short passage of the selected tune is played through an integral amplifier and loudspeaker whenever any one of the three control inputs is activated, making an ideal doorbell with a difference.

Circuit Description

In Figure 1, IC1 is an N channel MOS microcomputer-based synthesiser chip requiring supply and clock inputs for operation. Like most specialised micro integrated circuits all of the functional hardware is integral, leaving timing and addressing to user requirements. The ROM supply current being 50mA is far too high to ensure long battery life so the circuitry around TR1 switches off the supply at the end of a tune cycle. If door push 1 (connecting pins 3 and 4) is operated, TR1 is forward biased from the +V emitter supply, R2 to ground. R4 and zener diode D1 keep the supply within normal operating levels on IC1 pins 2 and 3 at +5V. The open drain output at IC1

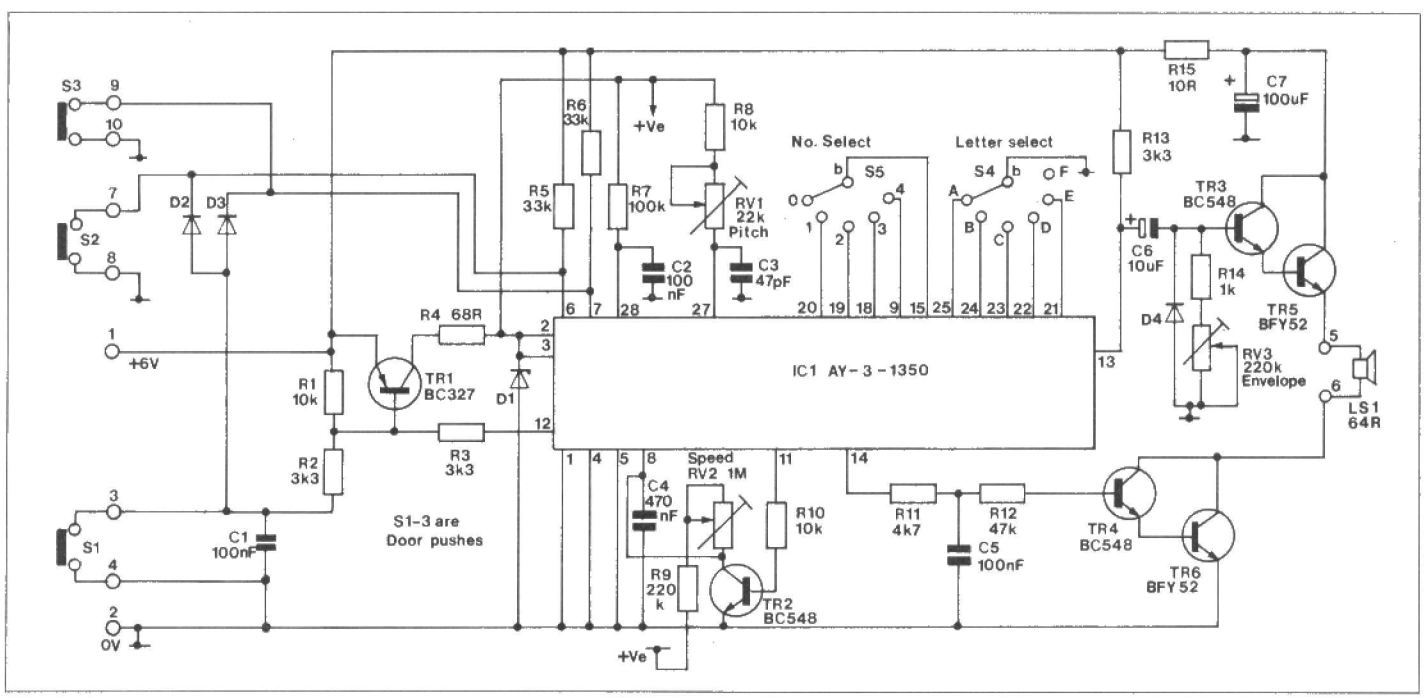
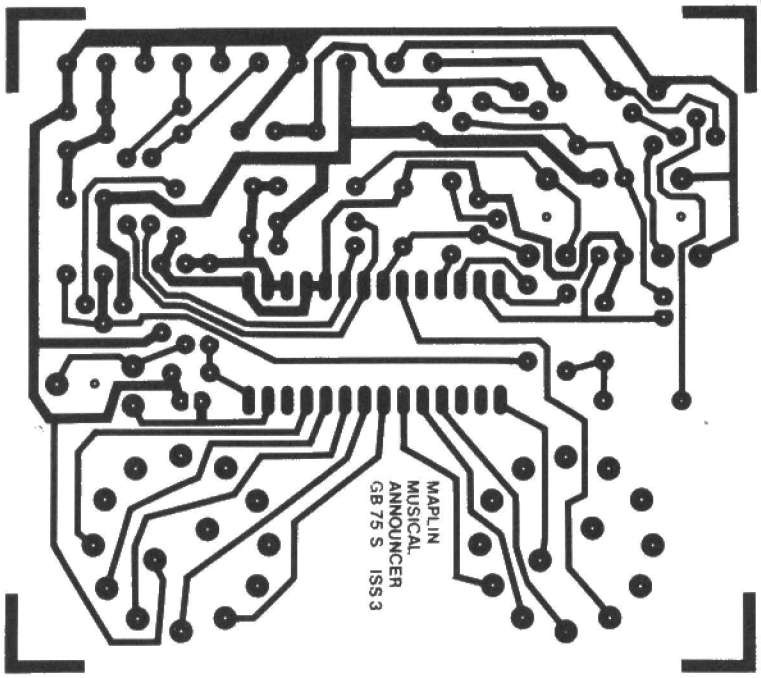


Figure 1. Circuit diagram



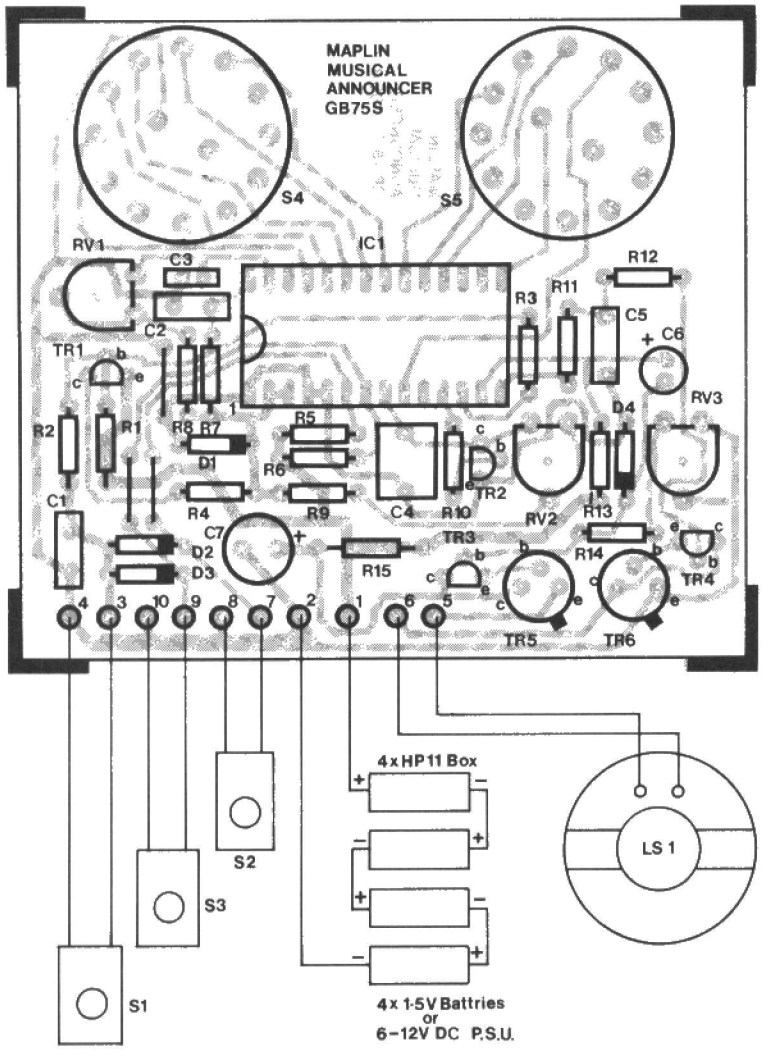
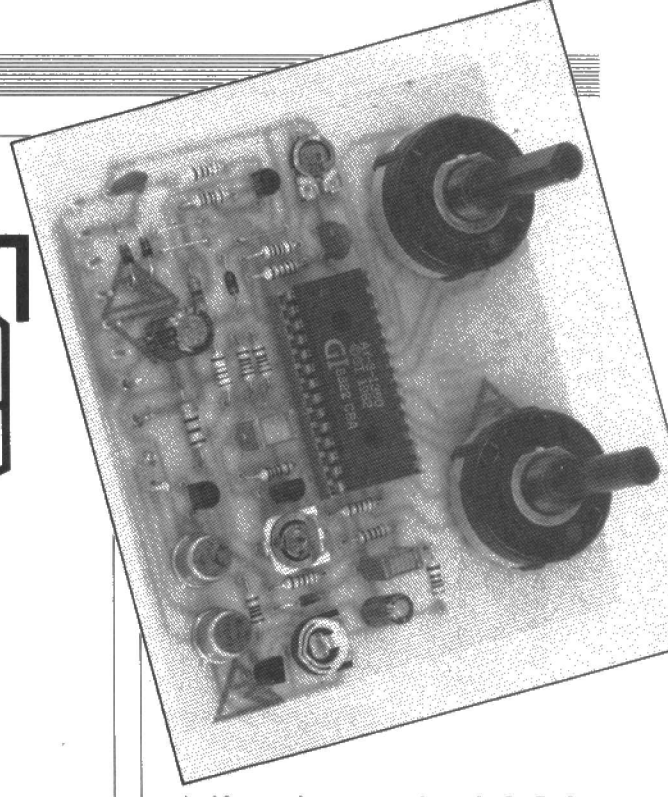


Figure 2. PCB track layout and overlay



pin 12 goes low approximately 6mS after activation, allowing for contact bounce, and TR1 is held on via R3. This allows the tune to continue if the push switch is released part way through the cycle. TR1 is finally released (off) at the end of the tune and the system is powered down. Push switch 2 (pins 7 and 8) and push switch 3 (pins 9 and 10) also power up the system as before but with a limited tunes facility. On both these switches, inputs produce repeated cycles if held closed, whereas input 1 generates a single cycle only.

RV1 and C3 determine the oscillator frequency from which the pitch of the output tune is generated, and RV1 spans approximately one octave. The speed or tempo of played tunes is determined by TR2, C4 and RV2. This pulse expander is a C.R. timer and transistor switch with RV2 controlling the tune speed. Output signals from IC1 pin 14 are first low pass filtered by R11, C5 and R12 before being buffered by emitter follower TR4. A 64 ohm speaker acts as the collector load for TR6 with the +V supply switched by TR5. For each note output from pin 14, an envelope trigger pulse is output from pin 13. A diode pump R13, C6 and D4 switches TR3 and TR5 either for the complete note cycle with a long decay time or, by adjusting RV3, for a short decay time. The audible effect is variable from organ-type sounds to staccato banjo or piano-type sounds being developed from the speaker. Both S1 and S2 are used in conjunction to select the desired tune or chime effects shown in Table 1.

Construction

Looking at Figure 2, you can see that three 24 SWG tinned copper wire links approximately 9mm long are required and should be fitted in position above D2 and D3 and next to TR1. Insert the three diodes D2, D3 and D4 and zener diode D1, followed by resistors R1 to R14. All diodes must be mounted correctly with the cathode or 'BAR' painted end according to the legend. These compo-

Select S4	Position S5	Tunes Available from each Push Switch Push Switch 1	Push Switch 2	Push Switch 3
A	0	Toreador		Toreador
B	0	William Tell		William Tell
C	0	Hallelujah Chorus		Hallelujah Chorus
D	0	Star Spangled Banner	D	Star Spangled Banner
E	0	Yankee Doodle	E	Yankee Doodle
F	0	Westminster Chime	S	Simple Chime
A	1	John Brown's Body	C	Toreador
B	1	Clementine	E	William Tell
C	1	God Save The Queen	N	Hallelujah Chorus
D	1	Colonel Bogey	D	Star Spangled Banner
E	1	Marseillaise	I	Yankee Doodle
F	1	Westminster Chime	N	Simple Chime
A	2	America America	G	Toreador
B	2	Deutschland Lied		William Tell
C	2	Wedding March	O	Hallelujah Chorus
D	2	Beethoven's 5th	C	Star Spangled Banner
E	2	Augustine	T	Yankee Doodle
F	2	Westminster Chime	A	Simple Chime
A	3	O Sole Mio	V	Toreador
B	3	Santa Lucia	E	William Tell
C	3	The End		Hallelujah Chorus
D	3	Blue Danube	C	Star Spangled Banner
E	3	Brahms' Lullaby	H	Yankee Doodle
F	3	Westminster Chime	I	Simple Chime
A	4	Hell's Bells	M	Toreador
B	4	Jingle Bells	E	William Tell
C	4	La Vie En Rose		Hallelujah Chorus
D	4	Star Wars		Star Spangled Banner
E	4	Beethoven's 9th		Yankee Doodle
F	4	Westminster Chime		Simple Chime

Table 1.

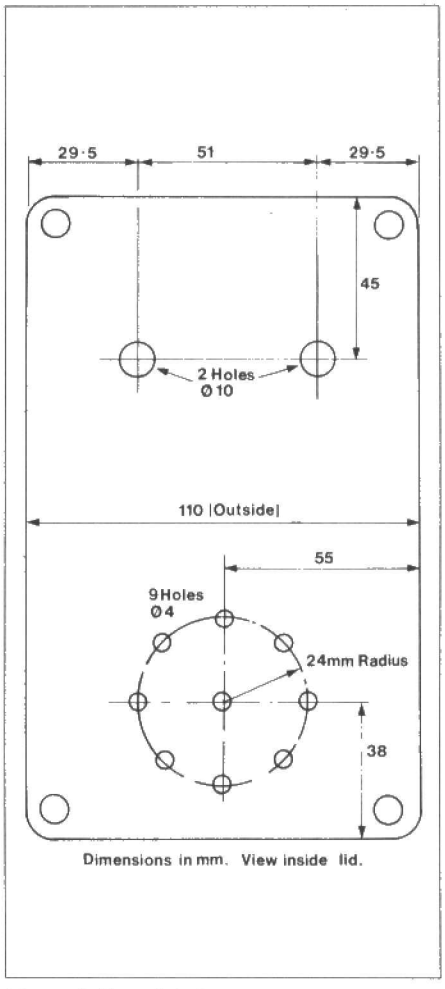


Figure 4. Case details

nents, as for resistors, require pre-bending of their leads before being inserted flat down onto the PCB. Now fit R15, the larger standard resistor. Next insert a 28 pin IC socket orientated so that the edge slot is the same as the legend, and solder all terminal legs in position. Capacitors can now be fitted and soldered in position. Take care not to wrench the leads on C4 and C5 as they could fall off if excess force is used. C6 and C7 are polarised electrolytics and the longest lead indicates +V and again must be inserted as per the legend. Fit RV1, 2 and 3 and all six transistors. TR5 and 6 will only insert in one position, but TR1 to 4, the 'D' shaped components, should be positioned according to the legend. Solder all components carefully, remove excess wires and insert Veropins 1 to 10 from the track side. Push them through the PCB with a soldering iron until their heads are flush with the track pads and solder them into position.

The 6-way rotary switches S4 and S5 need to be modified before fitting into the PCB. These switches will not fit through the board until each terminal end is cut off, leaving as much of the tang as possible (see Figure 3). After cutting, straighten up all fourteen tangs on each switch and push home into the PCB ensuring that the two centre terminals (A and B) line up correctly with their hole positions. Solder both switches carefully. S5 is only required to operate over five positions and this may be achieved by removing the circular stop ring from position 6 and refitting it in position five. S4 remains in six way operation. Finally, re-check all components and solder joints. Clean the track with a brush and thinners to remove flux, etc. and inspect for short circuits.

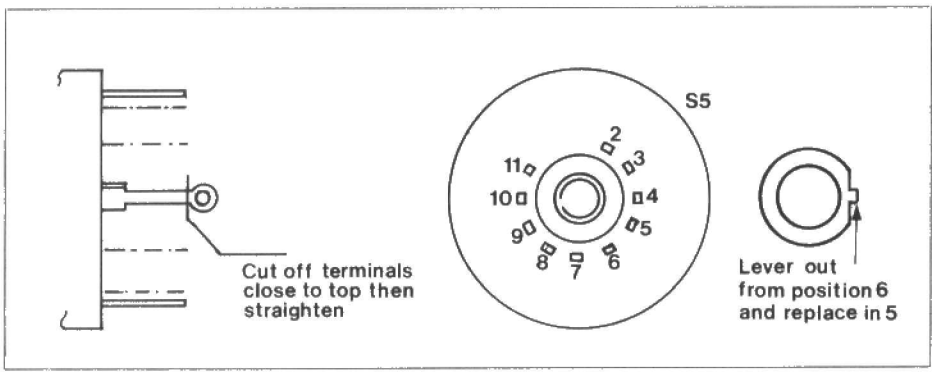


Figure 3. Switch assembly

Testing

Turn S4 and S5 fully anti-clockwise (group A and group 0) and set RV1, 2 and 3 wipers to half travel. Connect a 64 ohm speaker to pins 5 and 6 and either four 1.5V (C or D cells) batteries or a 6/12V DC power supply with the +V connected to pin 1 and the −V (0V) connected to pin 2. When using batteries, connect all your battery holders in series (see Figure 2) with the positive of one box wired to the negative of the next etc. This will leave one +V and one −V connection ready for terminating on the PCB. With IC1 still not fitted, switch on the power and short pins 3 and 4 together. Connect a voltmeter to 0V and pin 2 of the IC socket. A reading of 5 to 5.3V indicates correct conditions. Remove the short from pins 3 and 4, whereupon the voltage reading drops to 0V. Some high impedance meters may show a slow drop in level from 5 to 0V and digital meters will display random numbers below 20mV readings. Disconnect the supply, insert IC1 and re-connect the power again. Repeat the above tests for a reading of approximately 3.75 to 5.3 volts depending on the supply voltage. This time the first tune in Table 1 (Toreador) will play once only. Connect pins 9 and 10 only and the same tune will play again (push switch 3) and then repeat continually with short intervals until the connection is broken. Now connect pins 7 and 8 only and a Descending Octave Chime will be heard. This also repeats after a short delay until

the connection is broken.

With S5 still in the first position (group 0) turn S4 one step clockwise to position B. Repeat the three push switch tests as before referring to Table 1 for correct tunes and chimes. Push switch 2 only plays a descending chime and push switch 3 repeats the same six tunes for each position of S5. Only one tune at a time can be pre-set and played and no auto-incrementing or sequencing of tunes is available, but with twenty-eight combinations of tunes and chimes available, one should be able to prevent boredom from setting in.

Select any tune and connect pins 9 and 10 (push switch 3) together. Turn RV1 anti-clockwise to lower and clockwise to raise the pitch of the played tune. Note that the wiper is sensitive to touch and may cause modulation of the tune if not using an insulated trimming tool! Turn RV2 anti-clockwise to decrease and clockwise to increase the tempo of the playing tune. Final settings of these presets is left to the choice and the preference of the user.

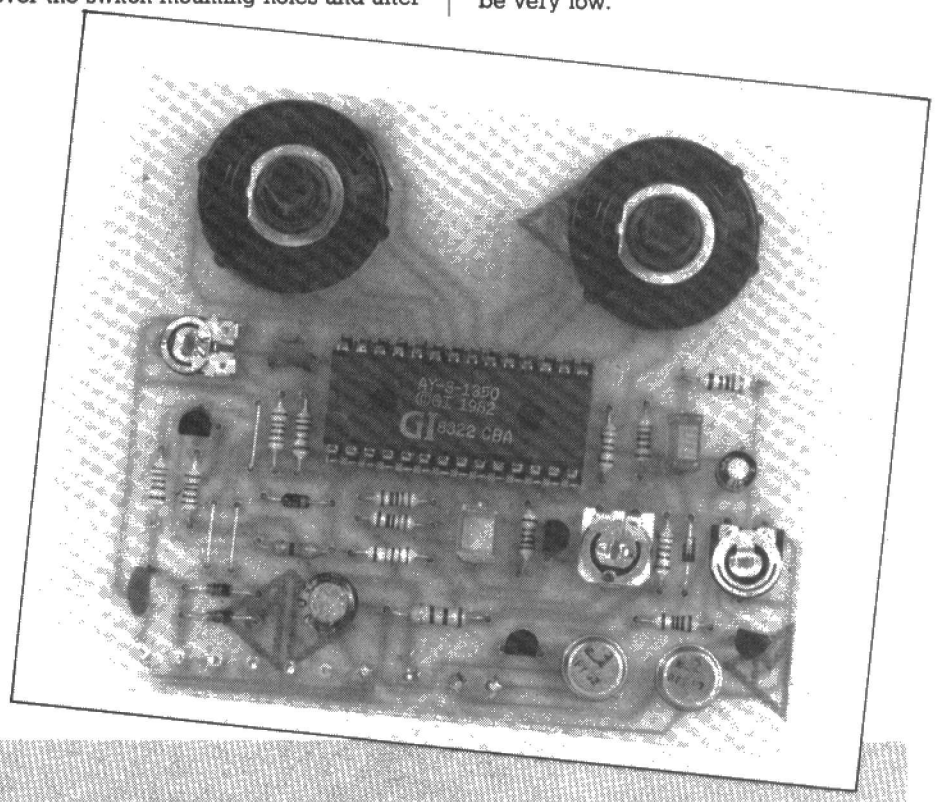
Now turn RV3 anti-clockwise to increase the note length and clockwise to decrease it. The full clockwise position will probably cut off tunes altogether as the pulse amplitude falls below the 1.2V conduction point of TR3. A final current check can be made with the power on and the module not activated, by connecting an ammeter in series with the +V supply and pin 1. No current reading should be indicated until one of the push switch inputs is connected, whereupon a reading of 45 to 60mA should be indicated.

Case Details

The Parts List recommends a suitable box for containing the module, speaker and four battery boxes. Two holes are drilled in the lid, for S4 and S5 to be fitted, which thus holds the PCB in position. Smaller holes are drilled in the lid to allow sound output from the speaker (see Figure 4). The speaker can be fitted to the box lid using Evo-stick which is lightly applied around the cardboard rim. Peel off and stick the Front Panel over the switch mounting holes and after cutting each spindle length to size, fit both knobs. Insert the batteries and assemble the box.

Announcer Use

The main function for this project would be as a doorbell with a front door push switch wired to pins 3 and 4 on the PCB. A secondary door, e.g. a back door, could be wired from a push switch to pins 9 and 10 and appropriate tune combinations selected for caller recognition. Switches used must be of a momentary push-to-make action to enable the power down facility, otherwise battery life will be very low.



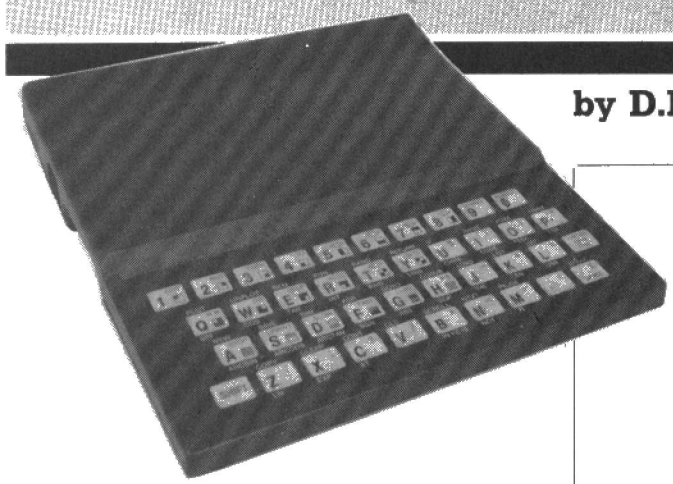
PARTS LIST FOR MUSICAL ANNOUNCER

RESISTORS: All 0.4W 1% Metal Film unless specified			
R1,8,10	10k	3	(M10K)
R2,3,13	3k3	3	(M3K3)
R4	68Ω	1	(M68R)
R5,6	33k	2	(M33K)
R7	100k	1	(M100K)
R9	220k	1	(M220K)
R11	4k7	1	(M4K7)
R12	47k	1	(M47K)
R14	1k	1	(M1K)
R15	10Ω ½W 5% Carbon Film	1	(S10R)
RV1	22k Hor S-Min Preset	1	(WR59P)
RV2	1M Hor S-Min Preset	1	(WR64U)
RV3	220k Hor S-Min Preset	1	(WR62S)
CAPACITORS			
C1,2	100nF Minidisc	2	(YR75S)
C3	47pF Ceramic	1	(WX52G)
C4	470nF Polycarbonate	1	(WW49D)
C5	100nF Polycarbonate	1	(WW41U)
C6	10μF 35V PC Electrolytic	1	(FF04E)
C7	100μF 25V PC Electrolytic	1	(FF11M)
SEMICONDUCTORS			
D1	BZY88C5V1	1	(QH07H)
D2,3,4	1N4148	3	(QL80B)
TR1	BC327	1	(QB66W)
TR2,3,4	BC548	3	(QB73Q)
TR5,6	BFY52	2	(QF29G)
IC1	AY-3-1350	1	(YY89W)
MISCELLANEOUS			
S4,5	Rotary SW6B 2-pole 6-way	2	(FF74R)
LS1	Hi-Z L/S 64R	1	(WF57M)
	Printed Circuit Board	1	(GB75S)
	Veropin 2145	1 pkt	(FL24B)
	DIL Socket 28-pin	1	(BL21X)
	Knob K7B	2	(YX02C)
OPTIONAL			
	Case Verobox 305	1	(LH51F)
	Cable Zip Wire	As req	(XR39N)
	HP11 Single Box	4	(BK45Y)
	Front Panel	1	(FM49D)
S1,2,3	Bell Push	3	(FQ09K)

A kit of parts (except Optional items) is available.
Order As LK57M (Announcer Kit) Price £13.50

The following parts used in this project are available separately, but are not included in our current catalogue.
FM49D Front Panel Price £1.55
GB75S Announcer PCB Price £1.99

The ZX81 and Your Boat



by D.I. Heaps Part Two

Introduction

In Part One, I gave details of how to build the sensing devices such as the Compass, the Anemometer, etc. In this second part, I will discuss the program and how to use it, and I will also show the additional circuitry required to process the data coming from the sensors. But first you need to obtain a Maplin ZX81 I/O Port Kit, which plugs into the ZX81 computer. Maplin's order code for this kit is LW76H and you will also require a 2 x 23-way edge connector (RK35Q) to be able to plug directly into the ZX81. The Kit is supplied with full construction details, but needs to be modified slightly for use in my project.

Tricks with your I/O Port.

The Maplin I/O port has been designed so that Port B can only be used as an output port. This is very useful in most circumstances as no further electronics are then needed to drive LED's etc. However, the main chip on the I/O port, the 8255A, is capable of many more operations than are mentioned in the Maplin I/O port literature.

First of all, we have to adapt the I/O board to accept input. This is a relatively simple and reversible job but requires care. You will need a soldering iron and a small pair of cutters or strong nail scissors. Figure 1 shows the whole I/O board layout but the section you need to concentrate on is the area around IC5 and IC6. You will see from Figure 2 that port B is buffered by two 7407 chips and two sets of 4.7kΩ resistors. It is necessary to remove the effect of these. Fortunately the input and output pins on the 7407 chips are next to each other and it is therefore easy to make connections between pins 1 and 2, 3 and 4, 5 and 6, and 8 and 9 to remove the buffers. It is also necessary to stop the positive supply to the chip by carefully cutting pin number 14. Similarly, it is necessary to cut the leads to the resistors. Port B can now be used as an input port but is no longer buffered so the same precautions will have to be taken as with ports A and C. (See I/O Port literature).

In the I/O Port documents supplied with the kit, Table 1 shows a list of Control Words. A further two are now required to configure Port B for input.

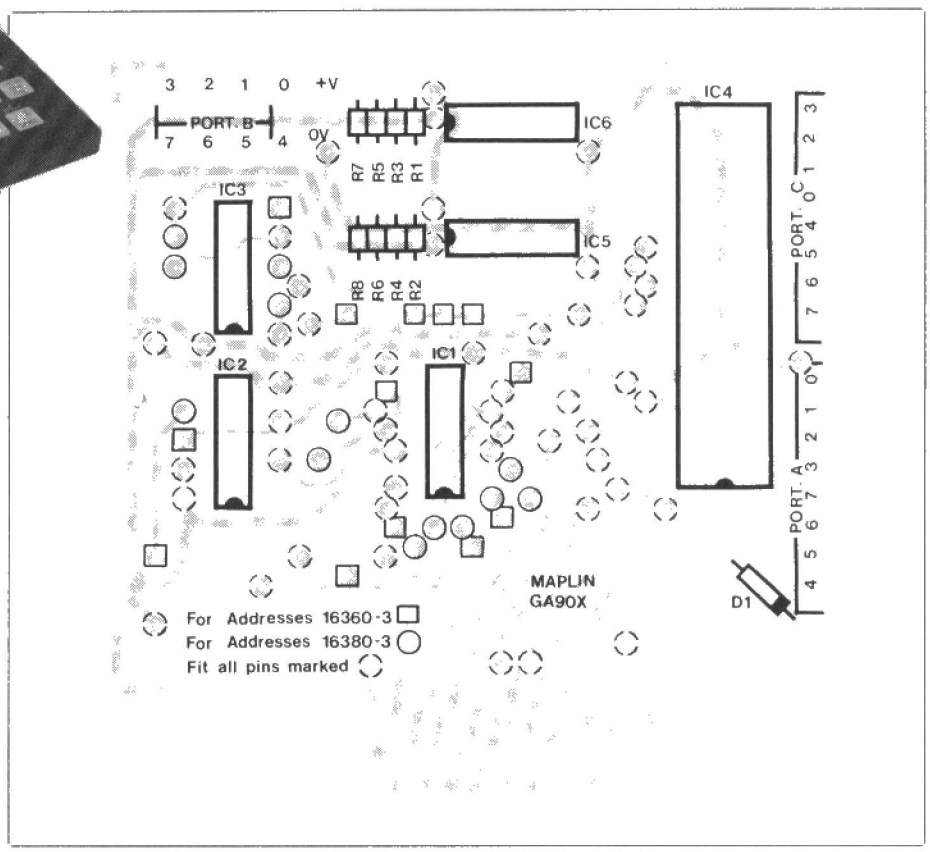


Figure 1. I/O Port PCB layout

Control Word	D7	D6	D5	D4	D3	D2	D1	D0	Port A	Port CU	Port CL	Port B
138	1	0	0	0	1	0	1	0	Output	Input	Output	Input
154	1	0	0	1	1	0	1	0	Input	Input	Output	Input

Table A

Refer to Table A for the new codes. Port C is split into two equal halves by several of the mode numbers. If you PEEK and POKE at the same time through port C, it will be necessary to subtract the POKEd number from the PEEKed number in order to obtain the correct PEEKed number. The number POKEd through a port is latched (remains there) until the next time the computer issues a new control word i.e. 16383,---. It is also worth noting that the port remains low until POKEd with a number greater than zero.

The Maplin I/O port has three ports, but you can expand this by selecting alternate data for a port. This system relies on the data selection chip, the 74157, and a spare data line on one of the other ports. The 74157 selects one of two data buses depending on the state of the select pin on the chip. Which spare data line is used to drive the chip will have to be carefully chosen according to the circumstances. In fact, I have implemented this idea in my design to expand Port B to receive data from several sources.

If you need to count events occurring rapidly, then the following may be useful. The simplest way of counting is to update a store in the computer on each cycle of the program. This is not very reliable and can only be used for the slower events. A better method is for the computer to read the state of an up-counting 8-bit chip every cycle or when needed. If longer counts are needed, then the input signal to the counter can be divided by say 100. (The 7493 can be wired to divide by several different numbers). Another problem which can be solved with a counter, is the measurement of speed and change in speed. Signals are counted by a four-bit counter and the computer samples the state of the counter every cycle. The difference between the two counts is calculated and then factored to give speed. The difficulty here is that the numbers go through zero and the straight subtraction of one number from another will not give the true number of events between samples. This problem is overcome by using the Sign function. A suitable program is:–

```
10 POKE 16383,138
20 LET A=PEEK 16382
30 PAUSE 10
40 LET B=PEEK 16382
50 LET C=B-A
60 LET N=C+8-8*SGN(C+1)
70 PRINT N
80 GOTO 20
```

Line 60 calculates the real difference between the two samples taken at lines 20 and 40. The system can be calibrated by including a multiplier in line 70. Note that all of the programs given including the main program, use the 16380 to 16383 bank of addresses which are selected by inserting track pins into the holes marked with a circle on the I/O Port board. You can however select addresses 16363 by inserting pins into the holes marked with a square on the board. If you do you would have to modify the programs accordingly.

One of the uses of the ports is to find the position of an article or instruct a machine to move to a position. An 8-bit port gives you 256 positions to select from. The instructions are issued as binary numbers through the port which come from decimal numbers in our program. Unfortunately, when changing from one to the other, more than one bit changes at a time even when changing from consecutive decimal numbers. If two bits have to change, it cannot be guaranteed that they will both change at exactly the same time. This can lead to a wrong number being issued or read by

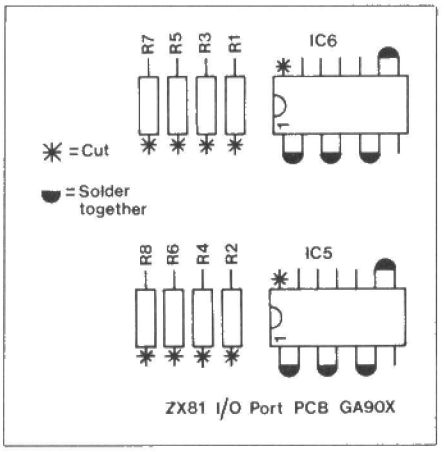


Figure 2. I/O Port modifications

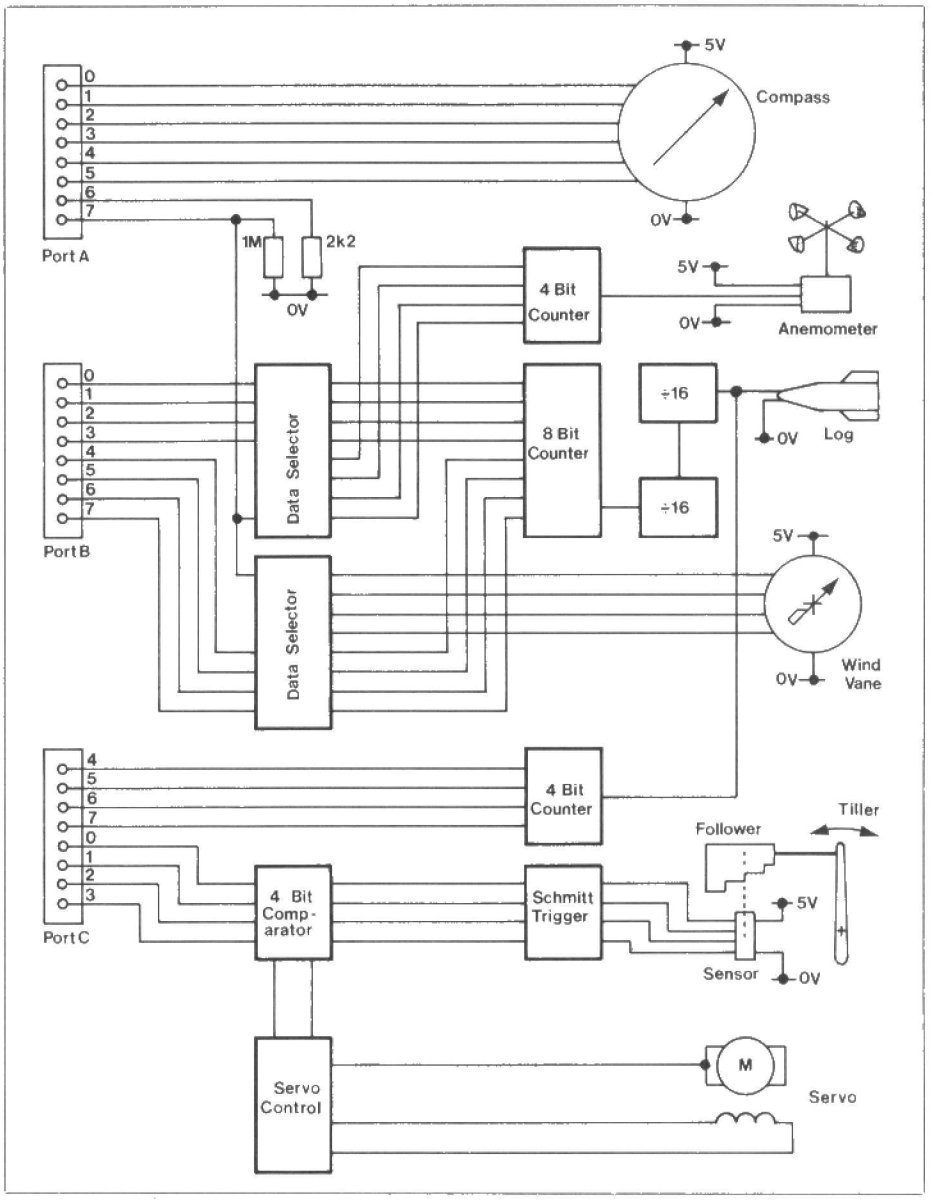


Figure 3. Block Schematic

the computer. This has been overcome by Grey coding the binary numbers. This arranges them in an order such that only one bit changes between consecutive numbers. This means that the numbers are all out of sequence but this is corrected for by the program. The Grey coded numbers are put into a string and then read out in true order on demand. The following example of Grey coding and stringing was used for the wind direction finder and gives a resolution of 22.5 degrees with four bits. Five bits would improve the resolution to 11.25 degrees and so on. The compass has six bits and has a resolution of 5.625 degrees.

Grey Coding Binary	Four bits String Decimal	Decimal	String
0000	0	0	000 degs.
0100	2	1	247
0101	10	2	023
0001	8	3	225
0011	12	4	338
0111	14	5	270
1111	15	6	315
1011	13	7	293
1001	9	8	067
1101	11	9	180
1100	3	10	045
1000	1	11	202
1010	5	12	090
1110	7	13	158
0110	6	14	113
0010	4	15	135

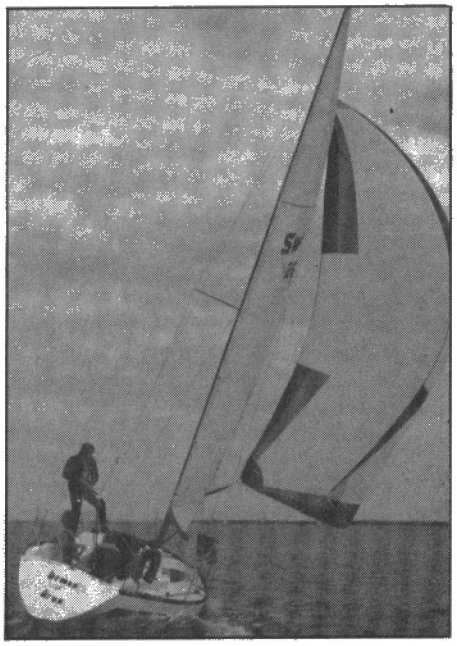
The following program will read Grey coded numbers through the lower half of port C and print sequential decimal numbers.

```
10 POKE 16383,138
20 LET F$="000247023225338270315293
671800452020901581131 35"
30 LET F=PEEK 16382
40 LET X=(3*F)/16
50 PRINT AT 10,10;F$(2+X-1 TO
2+X+1)
60 GOTO 30
```

These ideas can be expanded upon but it begins to be difficult to build the hardware to sufficient accuracy to match the degree of resolution achieved within the program.

Electronics

Figure 3 shows a block schematic of the additional circuitry required to interface between the sensors and the ZX81 I/O Port board. The compass is connected directly to Port A and the 6-bit binary pattern can be readily accessed. The Anemometer is joined to a 4-bit counter and the data can be read by Port B. The Log is coupled in a similar fashion but the information is read by Port C. The Log is also connected to signal dividers and then to an 8-bit counter to give distance travelled information. The Wind Vane is read by Port B to give wind direction. It was found most convenient to house all of the electronics for these parts together in one 'interface box', along with the power



pack to give the necessary voltages for the TTL chips, the I/O Port and the ZX81 itself.

Part of Port C is used to control the servo motor and also to sense the position of the tiller, so that adjustments can be made to keep the boat on the right course. All of the electronics could be housed in a 'Servo Controller Box' and it would include the servo drive transistors.

Schmitt Trigger

I have found that the signals between the tiller follower and the comparator chip will be more reliable if a Schmitt Trigger is included. I have put it in the line between the follower and the servo controller. It would be better if it were incorporated in the servo controller box. One of the problems with building circuits can be the variability between components. The I.R. parts in the follower have proved to be very variable. I had to

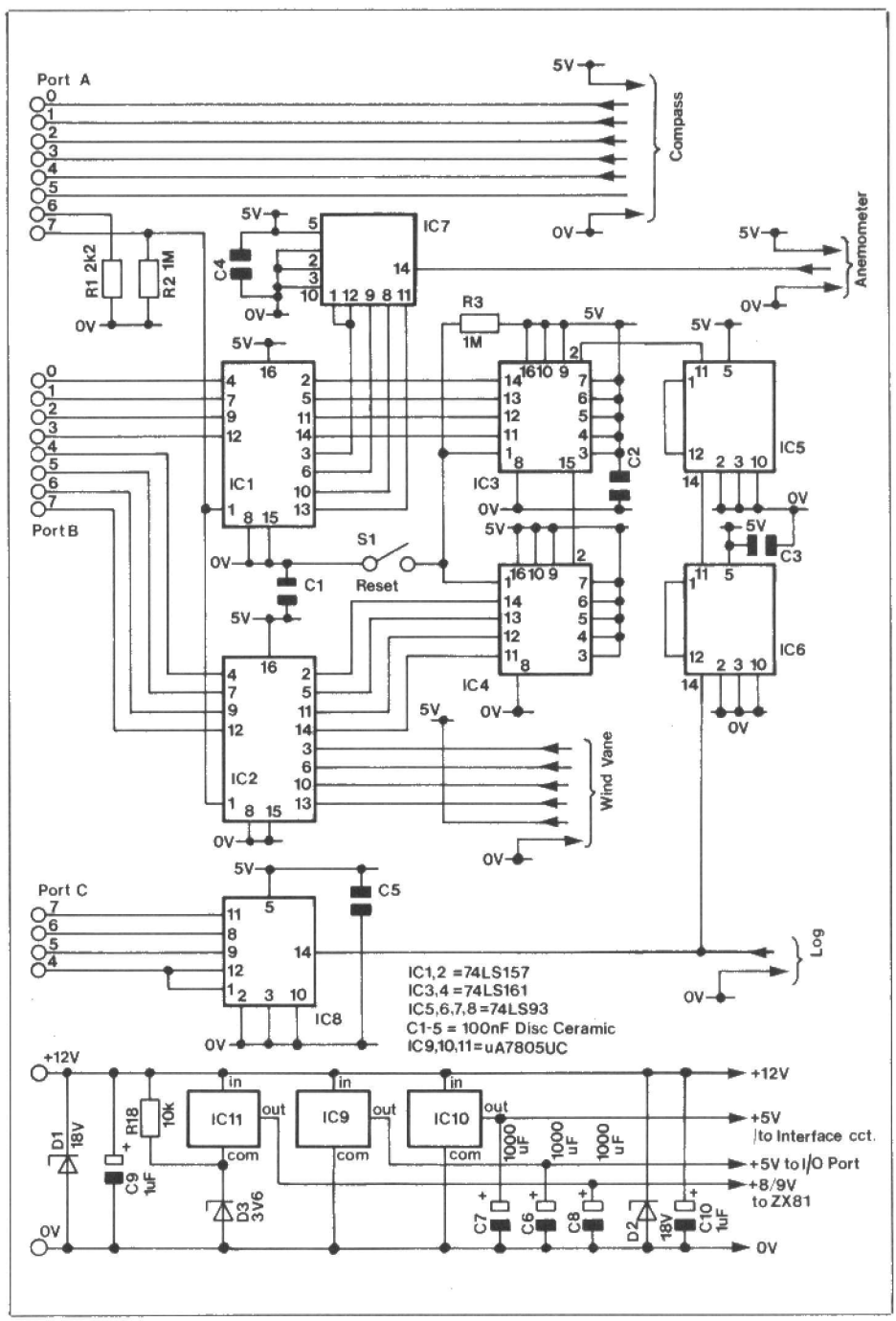


Figure 4. Interface Circuitry

```
   5 REM "IN"
  10 CLS
  15 PRINT "INTEGRATED NAVIGATIO
N PROGRAMME"
  20 PRINT AT 3,0;"THIS PROGRAM
STEERS YOUR BOAT "
  25 PRINT AT 4,0;"FROM INPUTS O
F TIDE,WIND AND     WHERE YOU WAN
T TO GO TO"
  30 PRINT AT 8,5;"SELECT ONE OF
:-"
  40 PRINT TAB 5;"(1)TIDES"
  45 PRINT TAB 5;"(2)NAVIGATION"
  50 PRINT TAB 5;"(3)WIND SPEED
AND DIRECTION"
  55 PRINT TAB 5;"(4)WATER SPEED
 AND DISTANCE"
  60 PRINT TAB 5;"(5)STEERING"
  65 PRINT TAB 5;"(6)
"
  68 PRINT AT 18,0;"TO RETURN TO
 THIS PAGE- PRESS R"
  70 PRINT AT 21,0;"TYPE NUMBER
REQUIRED:-"
  75 INPUT JO
  80 IF JO<1 OR JO>6 THEN GOTO 7
0
  85 IF JO=1 THEN GOSUB 1000
  90 IF JO=2 THEN GOSUB 2000
  95 IF JO=3 THEN GOSUB 3000
 100 IF JO=4 THEN GOSUB 4000
 105 IF JO=5 THEN GOSUB 5000
 110 IF JO=6 THEN GOSUB 6000
 115 GOTO 1
1000 CLS
1005 PRINT "TIDES"
1010 PRINT AT 2,0;"THIS PROGRAM
CALCULATES THE     AVERAGE TIDE
AND DIRECTION FROM HOURLY TIDAL
DATA"
1015 PRINT AT 6,0;"ENTER THE TID
E SPEED AND        DIRECTION (AL
WAYS MEASURED CLOCKWISE FROM NOR
TH) FOR EACH HOUR"
1020 IF INKEY$="" THEN GOTO 1025
1030 LET C=0
1035 LET D=0
1037 LET N=0
1040 PRINT AT 10,0;"TIDE STRENGT
H="
1045 INPUT T1
1046 LET N=N+1
1050 PRINT AT 10,20;"          "
1055 PRINT AT 10,20;T1
1060 PRINT AT 11,0;"TIDE ANGLE="
1065 INPUT QT
1070 LET QT1=QT/57.296
1075 PRINT AT 11,20;"          "
1080 PRINT AT 11,20;QT
1085 LET A1=T1*COS QT1
1090 LET B1=T1*SIN QT1
1095 LET C=C+A1
1100 LET D=D+B1
1105 PRINT AT 13,0;"EASTINGS="
1110 PRINT AT 13,20;"          "
1115 PRINT AT 13,20;D
1120 PRINT AT 14,0;"NORTHINGS="
1125 PRINT AT 14,20;"          "
1130 PRINT AT 14,20;C
1135 PRINT AT 16,0;"IF FURTHER D
ATA TO BE ENTERED - PRESS Y,IF N
OT PRESS N"
1140 IF INKEY$="" THEN GOTO 1140
1145 IF INKEY$="Y" THEN GOTO 104
0
1155 LET E=C*C+D*D
1160 PRINT AT 20,0;"AVERAGE TIDE
="
1165 PRINT AT 20,20;"          "
1170 LET F1=SQR E/N
1171 PRINT AT 20,20;F1
1175 PRINT AT 21,0;"AVER.TIDE AN
GLE ="
1180 PRINT AT 21,20;"          "
1185 LET F=D/C
1190 LET G=ATN F
1195 PRINT AT 21,20;G*57.296
1200 IF INKEY$="" THEN GOTO 1200
1205 IF INKEY$="R" THEN GOTO 1
2000 CLS
2005 PRINT "NAVIGATION"
2010 PRINT AT 2,0;"THIS PROGRAM
CALCULATES COURSE    AND DISTANCE
 FOR MOTORING OR     SAILING"
2015 PRINT AT 6,0;"DISTANCE A TO
 B="
2020 INPUT AB
2025 PRINT AT 6,20;AB
2030 PRINT AT 7,0;"ANGLE OF B="
2040 INPUT QBA
2045 PRINT AT 7,20;QBA
2050 PRINT AT 8,0;"BOAT SPEED="
2055 INPUT SB
2060 PRINT AT 8,20;SB
2065 PRINT AT 9,0;"TIDE SPEED="
2070 INPUT ST
2075 PRINT AT 9,20;ST
2080 PRINT AT 10,0;"TIDE ANGLE="
2085 INPUT QT
2090 PRINT AT 10,20;QT
2095 PRINT AT 11,0;"WIND ANGLE="
2100 INPUT QW
2105 PRINT AT 11,20;QW
2110 PRINT AT 12,0;"WIND/BOAT AN
GLE="
2115 INPUT QBW
2120 PRINT AT 12,20;QBW
2125 LET Z=QBA/57.296
2130 LET N=QW/57.296
2135 LET Y=QT/57.296
2140 LET M=QBW/57.296
2145 LET A=PI+Z-Y
2150 LET B=SIN A
2155 LET C=Y-Z-ASN (ST*B/SB)
2160 LET A1B=AB*B/SIN C
2165 LET D=Y-C
2170 PRINT AT 14,0;"IF NOT TACKI
NG STEER- Q=";D*57.296
2175 PRINT AT 15,17;"MILES=";A1B
2180 PRINT AT 18,0;"IF TACKING S
TEER-"
2185 LET L=D
2190 LET O=PI-2*M
2195 LET P=N+M-L
2200 LET Q=L+M-N
2205 LET F=SIN P
2210 LET G=SIN O
2215 LET H=SIN Q
2220 LET AC=A1B*F/G
2225 LET CB=A1B*H/G
2230 LET QL1=2*PI-Q+L
2235 LET QL2=PI-O-Q+L
2236 IF QL1>2*PI THEN LET QL1=QL
1-2*PI
2237 IF QL2>2*PI THEN LET QL2=QL
2-2*PI
2240 PRINT AT 18,18;"QL1=";QL1*5
7.296
2245 PRINT AT 19,17;"LEG1=";AC
2250 PRINT AT 20,18;"QL2=";QL2*5
7.296
2255 PRINT AT 21,17;"LEG2=";CB
2260 IF AC<0 OR CB<0 OR QL1<0 OR
 QL2<0 THEN GOTO 2270
2265 IF AC>=0 OR CB>=0 OR QL1>=0
 OR QL2>=0 THEN GOTO 2280
2270 PRINT AT 21,0;"NO TACKING"
2275 IF INKEY$="" THEN GOTO 2275
2280 IF INKEY$="R" THEN RETURN
2290 PRINT AT 21,0;"TACKING"
2295 GOTO 2275
3000 CLS
3005 PRINT "WIND SPEED AND DIREC
TION"
3010 POKE 16383,138
3012 POKE 16380,128
3013 POKE 16382,3
3015 GOSUB 3210
3020 LET O=M
3025 GOSUB 3210
3030 LET P=M
3035 LET Q=P-O
3040 LET N=Q+8-8*SGN (Q+1)
3045 PRINT AT 10,1;"WIND SPEED"
3050 PRINT AT 12,5;"          "
3055 PRINT AT 12,5;N
3060 LET F$="000247023225338270315293067180045202090158113135"
3065 LET R=A-P
3070 LET F=R
3075 LET X=(3*F)/16
3080 PRINT AT 10,16;"WIND DIRECT
ION"
3085 PRINT AT 12,22;"      "
3090 PRINT AT 12,22;F$(2+X-1 TO
2+X+1)
3095 IF INKEY$="R" THEN GOTO 1
3100 GOTO 3010
3210 LET A=PEEK 16381
3215 LET B=INT (A/2)
3220 IF 2*B<A THEN LET Z=1
3225 IF 2*B>=A THEN LET Z=0
3235 LET C=INT (B/2)
3240 IF 2*C<B THEN LET Y=1
3245 IF 2*C>=B THEN LET Y=0
3255 LET D=INT (C/2)
3260 IF 2*D<C THEN LET X=1
3265 IF 2*D>=C THEN LET X=0
3275 LET E=INT (D/2)
3280 IF 2*E<D THEN LET W=1
3285 IF 2*E>=D THEN LET W=0
3290 LET M=Z*1+Y*2+X*4+W*8
3295 RETURN
4000 CLS
4005 PRINT "WATER SPEED AND DIST
ANCE"
4010 PRINT AT 3,0;"THIS PROGRAMM
E GIVES BOAT SPEED AND DISTANCE
TRAVELLED THROUGH  THE WATER"
4020 POKE 16383,138
4025 POKE 16380,0
4026 POKE 16382,3
4030 LET A=PEEK 16381
4035 GOSUB 4095
```

```
4040 LET O=M
4045 GOSUB 4095
4050 LET P=M
4055 LET Q=P-O
4060 LET N=Q+8-8*SGN (Q+1)
4065 PRINT AT 10,1;"WATER SPEED"
4070 PRINT AT 12,5;"          "
4075 PRINT AT 12,5;N
4080 PRINT AT 10,16;"WATER DISTA
NCE"
4085 PRINT AT 12,22;"          "
4090 PRINT AT 12,22;A
4091 IF INKEY$="R" THEN GOTO 1
4092 GOTO 4030
4095 LET M=(PEEK 16382-3)/16
4100 PAUSE 10
4105 RETURN
5000 CLS
5005 PRINT "STEERING"
5010 PRINT AT 3,0;"THIS PROGRAM
 STEERS THE BOAT   FROM COMPASS
AND REQUIRED COURSE"
5020 PRINT AT 8,0;"INPUT COMPASS
 AND REQUIRED      COURSE- PRESS
 N FOR NEW COURSE"
5025 LET Z=3
5030 LET C=0
5035 LET R=-1
5040 LET A$="11"
5041 LET B$="77"
5042 LET C$="000354264270084090 1
80174"
5043 LET C$=C$+"006349259276079 0
96186169"
5044 LET C$=C$+"017338248287068 1
07197158"
5045 LET C$=C$+"011343253281073 1
01191163"
5046 LET C$=C$+"039315225309045 1
29219135"
5047 LET C$=C$+"034321231304051 1
24214141"
5048 LET C$=C$+"023332242293062 1
13203152"
5049 LET C$=C$+"028326236298056 1
18208146"
5050 POKE 16383,154
5055 PRINT AT 12,5;"COMPASS"
5060 PRINT AT 12,20;"REQUIRED"
5061 PRINT AT 18,0;"STEER CODE="
5065 IF INKEY$="R" THEN GOTO 1
5068 PRINT AT 18,15;"    "
5069 PRINT AT 18,15;Z
5070 POKE 16382,Z
5071 IF R>=0 THEN GOTO 5073
5072 INPUT R
5073 IF INKEY$="N" THEN GOTO 507
2
5075 LET X=(PEEK 16380)*3
5078 LET C=VAL (C$(2+X-1 TO 2+X+
1))
5079 PRINT AT 14,7;"    "
5080 PRINT AT 14,7;C
5081 PRINT AT 14,22;"    "
5082 PRINT AT 14,22;R
5085 IF C>180 AND C<=360 AND R>=
0 AND R<180 THEN GOTO 5300
5090 IF R>180 AND R<=360 AND C>=
0 AND C<180 THEN GOTO 5400
5095 LET D=C-R
5105 IF D>-5.625 AND D<5.625 THE
N GOTO 5500
5110 IF D>0 THEN GOTO 5155
5115 IF D<0 THEN GOTO 5120
5120 IF D<-16.875 THEN GOTO 5700
5125 LET D=INT (D/5.625)+1
5130 LET X=ABS (D)
5140 LET Z=VAL (A$(X))
5145 GOTO 5065
5155 IF D>16.875 THEN GOTO 5600
5160 LET D=INT (D/5.625)
5165 LET Y=ABS (D)
5175 LET Z=VAL (B$(Y))
5180 GOTO 5065
5300 LET C=360-C
5310 LET D=C+R
5315 IF D<5.625 THEN GOTO 5500
5325 IF D>16.875 THEN GOTO 5700
5330 LET D=INT (D/5.625)
5335 LET Z=VAL (A$(D))
5340 GOTO 5065
5400 LET R1=360-R
5405 LET D=ABS (C+R1)
5410 IF D<5.625 THEN GOTO 5500
5420 GOTO 5155
5500 LET Z=3
5505 GOTO 5065
5600 LET Z=15
5605 GOTO 5065
5700 LET Z=0
5705 GOTO 5065
```

experiment to strike the best balance of resistors which will take the trigger low enough to read low and high enough to read high (0.9 and 1.7 volts respectively). The values I have shown for R4 to R7 should be a good starting point though.

The interface circuitry is shown in Figure 4 and the servo control box circuitry is shown in Figure 5. Remember that you do not have to lump all of the electronics together as I have; in fact you may have a better solution in mind already.

As you will see from Figure 6, the system requires a range of supplies. I have provided these, either directly from the 12 volt accumulator in the boat or from a separate (old) one through three 7805's. The TV and the servo require

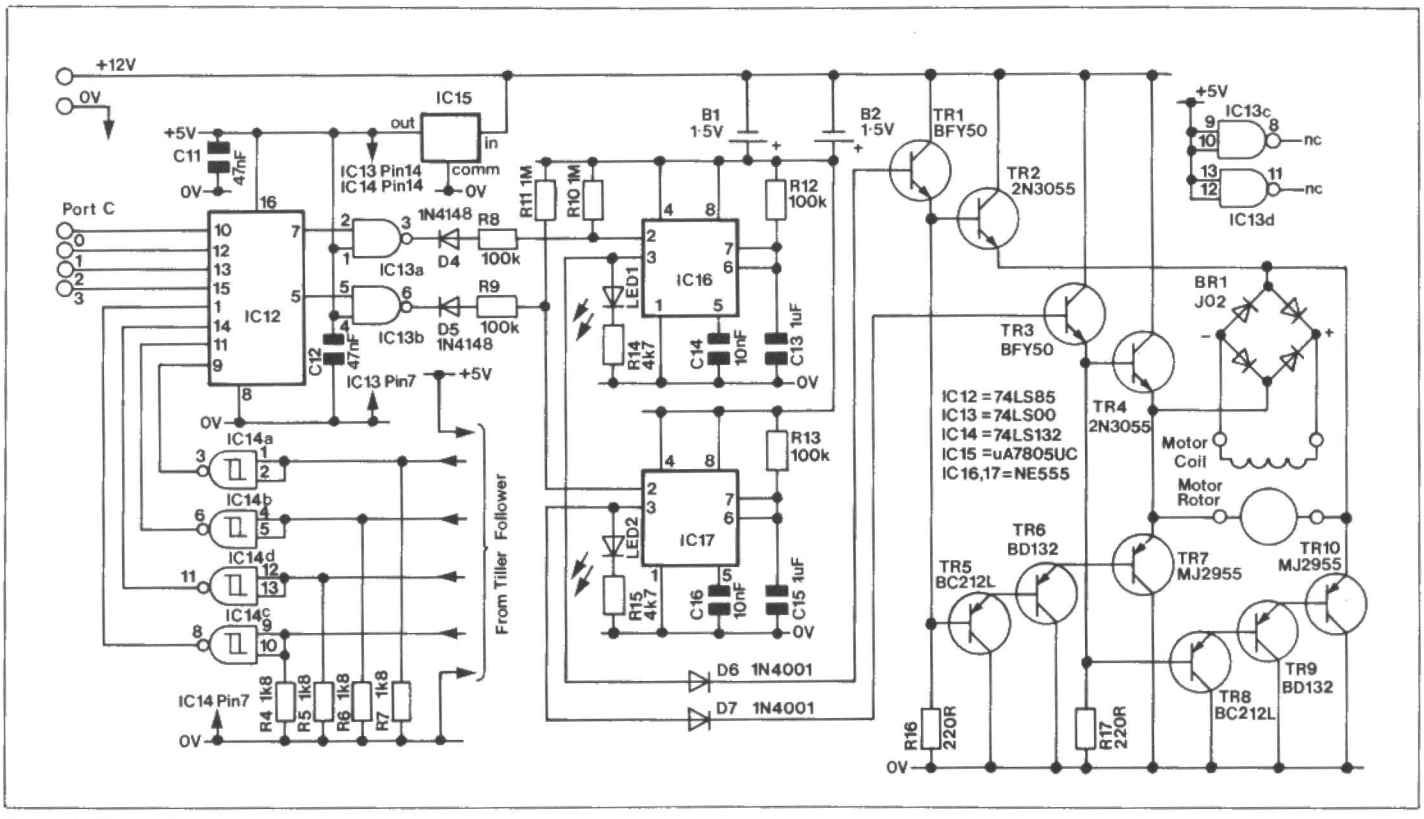


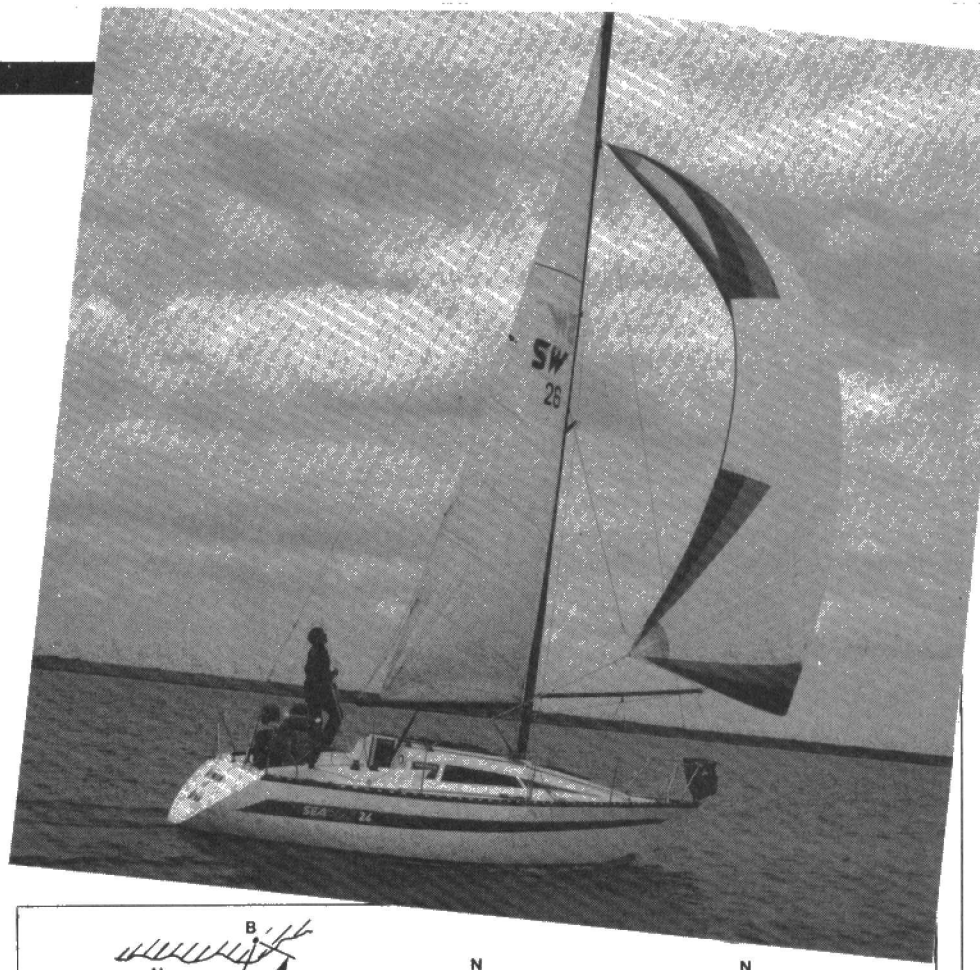
Figure 5. Servo Circuitry

relatively large currents and are wired to the boat accumulator. The TV can be switched off when not in use – during steering. The rest of the system uses very small amounts of current, but the voltages must be steady and free from 'spikes' caused by generators etc. The regulated voltages are supplied through a power pack which is made from three 7805's. Two supply 5 volts and drive the I/O port and the interface electronics. The third one is balanced to supply 8 to 9 volts for the ZX81. The circuit is shown in Figure 4. The 7805's get quite hot and should be fitted with a heat sink of some $10cm^2$. I have fitted them into the interface, but feel that they would probably be better in their own box to help dissipate the heat.

Program Operation

Below are a set of instructions which should be followed when using the program. Enter the program from the tape and press 'RUN' followed by 'NEW LINE'. A list of options will appear on the screen. Choose the one you require and enter the number on the keyboard. When you have finished with that option, press 'R' and you will return to the main menu. Option 1 is the tidal information and to use it you must first estimate how many hours the journey will take. From the Almanac, obtain the speed and direction of the tide for each hour. Enter them in the computer as required by the TV display. You will need to press 'Y' after entering each pair of inputs. When all have been entered, press 'N' and the program will display the average strength and direction of the tide during the time of the journey. All tidal strengths are positive towards the port and the angle is measured as positive in a clockwise direction from magnetic north. The program also displays 'Eastings and Northings' of the vectored sum of the tides entered. This gives the position of where you start from if you wish to plot your course. It can be useful to check on whether or not you have entered things correctly into the computer when using option 2.

Option 2, the navigation program, will ask for the inputs one at a time. Distances should be measured in nautical miles and speed in knots. The positive direction for distance is away from the starting point, and for tides, towards it. In the case of wind, it is towards the starting point. Angles must be measured in degrees from magnetic north and in a clockwise direction – see Figure 7. The final item required by the program is the angle that the boat will sail to the wind. This is intended to be your estimate and relies on your experience of the boat. If you are not sure how well the boat will sail then run the program several times entering different boat speeds and angles to the wind noting the different courses and distances through the water. By comparing the output you will be able to judge whether to sail slowly close to the wind or bear off a little. If you are motoring, still enter the data or else the computer will not continue. If you judge



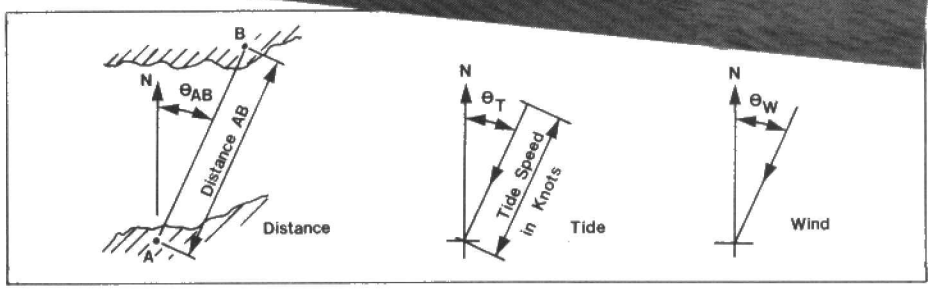


Figure 7. Navigation Geometry

that the conditions don't favour sailing, the first outputs will give you the direct course and the distance through the water. If however, you choose to sail and the wind is against you, the second set of outputs will be the courses and distances through the water for tacking. The program will also tell you whether you can sail straight there or will have to tack.

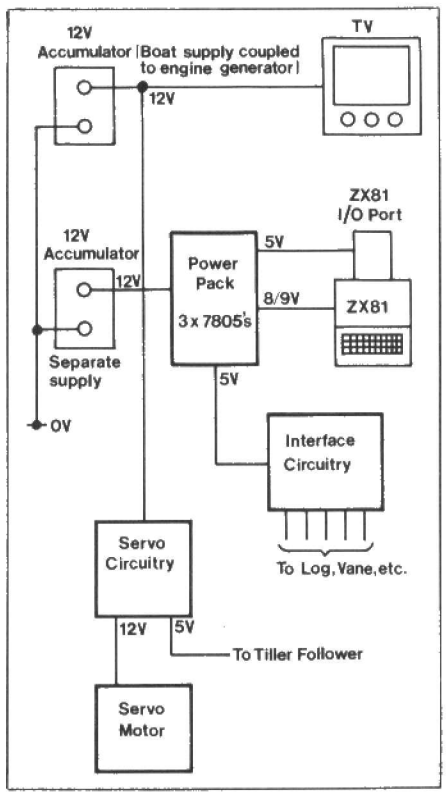


Figure 6. Power Supply Distribution

Option 3 gives the wind speed and direction as calculated from the information supplied by the Wind Vane and the Anemometer. The figures are displayed on the screen and are related to the boat.

Option 4 shows the water speed and the distance travelled through water. This information is supplied by the Log. The distance travelled is stored on an external
chip and read on demand by the computer. This can be reset by pressing the 'Distance Reset' button in the interface circuit.

Option 5 is the steering program. To use this program you only enter the course you want to steer and the computer will keep the boat to this course. If you need to tack at some time during the journey, you will have to keep an eye on how far you have travelled. This can be done by calling up option 4. The courses to steer can, of course, be calculated using option 2. New courses can be entered by pressing 'N'.

Finally, if you do not wish to sit and type in the program, a tape is obtainable from myself for £5.00. Just write to me at 28 Stirling Way, Horsham, Sussex, RH13 5RP, enclosing a Cheque/Postal Order made payable to D.I. Heaps.
Happy Sailing!

MAINS CONTROLLER FOR 8-CHANNEL FLUID DETECTOR

by Nigel Fawcett

In response to the 8-channel fluid detector project in Vol. 3 Number 11, many requests have been received asking for more detailed information on how to use the digital outputs to control mains devices. The first, and simplest form, was how to replace any of the LED's with the coil of a relay. This is achieved by removing the 1k load resistor (R3, 5, 7, 9, 11, 13, 15, 17 depending on which channel is being used), and replacing it with a 100 ohm resistor. The LED is also removed and this is replaced by the coil of the relay. The relay should have a coil resistance of approximately 300 ohms, and a nominal voltage of 12V DC. The new output stage is shown in Figure 1.

If a channel is used to switch the mains and the LED is also required then the circuit shown in Figure 1 is needed in addition to the output stage on the Fluid Detector PCB. A flying lead from the IC side of the 10k resistor (IC3 and R4, 6, 10, 12, 14, 16, 18, depending on which channel is being used) must be taken to a separate board with the relay drive circuit on it. Refer to Figure 2. This modification satisfies the requirements of the nurseryman and his greenhouse mist sprayers, as described in the original article.

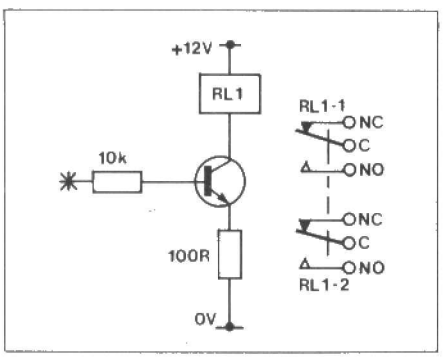


Figure 1. Relay driver

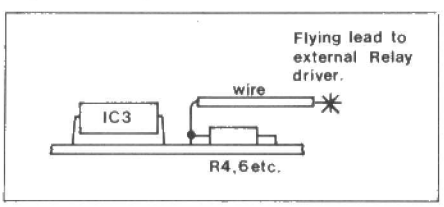
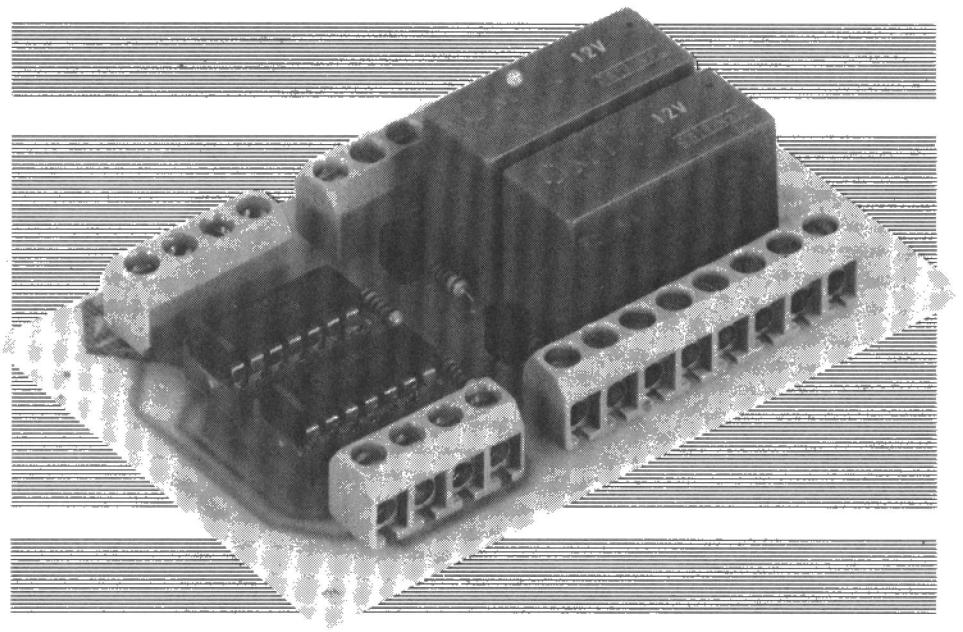


Figure 2.



The second and more complicated control circuit is used, for example, where a tank is gradually filling up with water, which must be pumped out to prevent the tank from overflowing. In addition, the water flowing into the tank can be turned off by mains controlled valves. It is decided that the pump should not start emptying the tank until it is half full, but should continue to pump out the contents until the tank is empty. If the inflow of liquid exceeds the outflow and the tank becomes full, then the inlet valves must be closed and remain closed until the tank is half empty. The requirements for the pump and the inlet valves

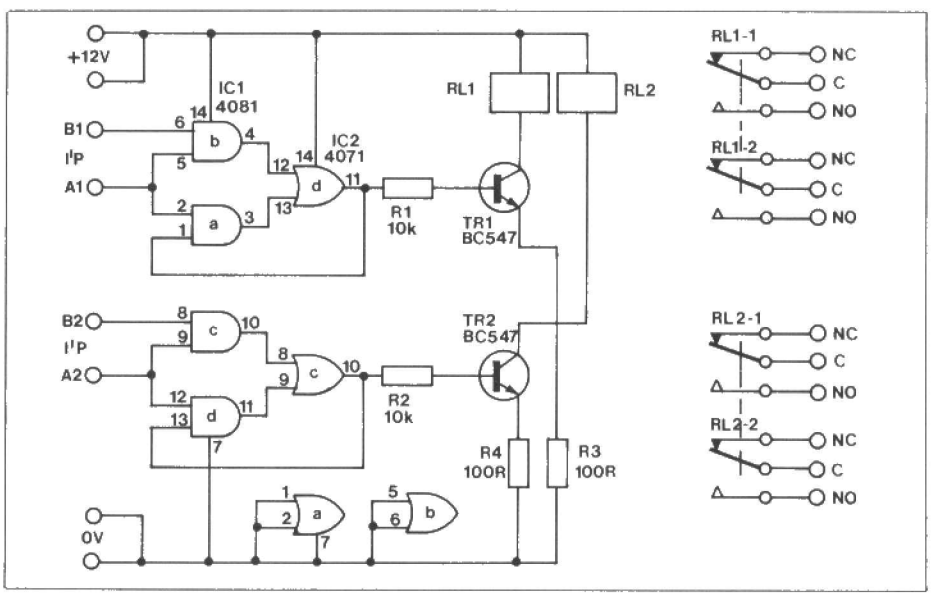


Figure 3. Circuit diagram

are actually the same, so two identical circuits are required. The logic for the circuit shown in Figure 3 is that the relay should be energised when two separate inputs are both 'high' and remain energised until both return to the 'low' state. In point of fact, only the 'A' input need go 'low' to release the relay, but the application hardware ensures that the 'B' input must logically already be 'low' before the 'A' input too becomes 'low'.

This second modification is the one that was used for the darkroom/workshop described in the original article. Figure 5 demonstrates this application in use.

Circuit Description

The circuit consists of two identical circuits, each of which comprise two AND gates, one OR gate, a relay driver and a relay. The 'A' input is used as the control input and is connected to both of the AND gates. The 'B' input is connected to one of the AND gates, and the outputs from the AND gates are in turn connected to the inputs of the OR gate. The output from the OR gate is used to control the relay, but is also fed back to the input of the other AND gate. When 'A' and 'B' are both low then the inputs to the OR gate are also low, holding the output low as well. When the 'A' input is taken high nothing changes, but when the 'B' input is also taken high the output from that AND gate goes high and in turn the OR gate output goes high, this switches the relay driver, but as the output is also fed back to the second AND gate, the output from the OR gate is latched high even when the 'B' input returns to the low state. The OR gate output will only return low when 'A' is also returned to the low state.

Construction

All components are fitted on the printed circuit board (see Figure 4). Start by inserting, and soldering the resistors, proceed with the IC sockets and PC terminals, followed by the transistors and the relays. Finally insert the IC's into their sockets. The 12V power supply is taken from the 8-channel fluid detector. Provision has been made on the PC terminals for the relays, for connecting earth wires, one of these should be taken to the earth point on the power supply.

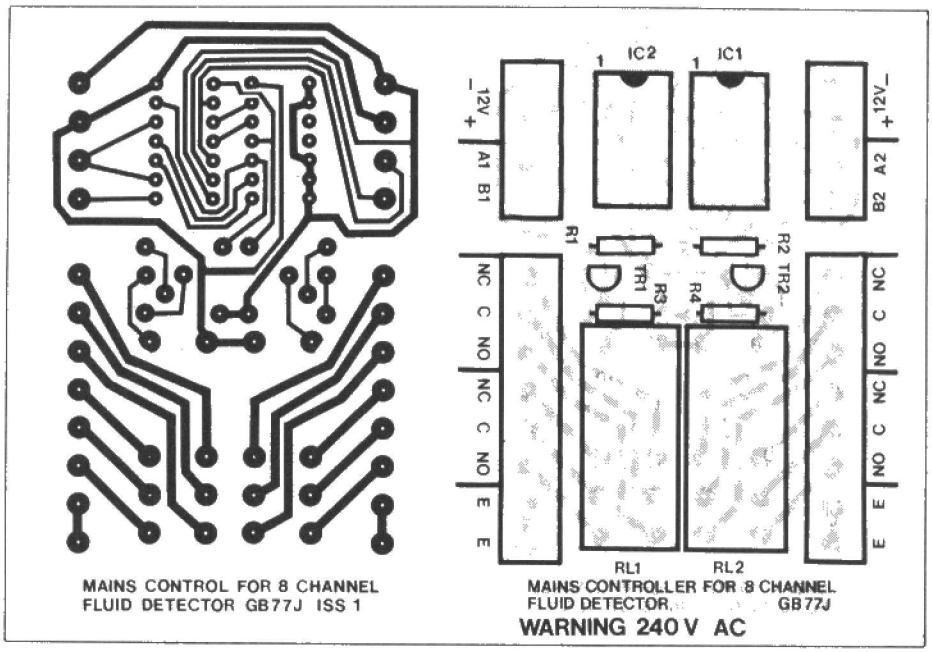


Figure 4. PCB track layout and overlay

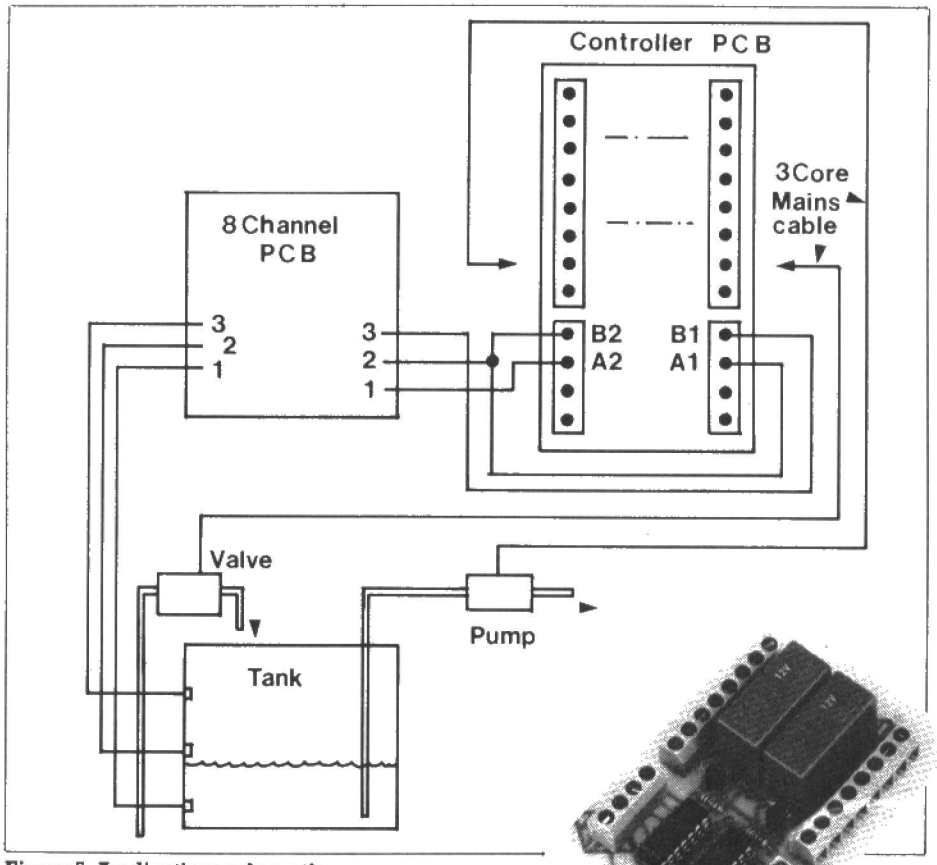
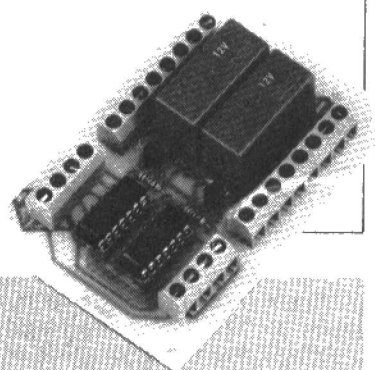


Figure 5. Applications schematic



PARTS LIST FOR MAINS CONTROLLER

RESISTORS: All 0.4W 1% Metal Film			
R1,2	10k	2	(M10K)
R3,4	100Ω	2	(M100R)
SEMICONDUCTORS			
TR1,2	BC547	2	(QQ14Q)
IC1	4081BE	1	(QW48C)
IC2	4071BE	1	(QW43W)
MISCELLANEOUS			
RL1,2	5A Mains Relay	2	(YX98G)
Printed Circuit Board		1	(GB77J)
PC Terminal 4-way		2	(RK73Q)
PC Terminal 8-way		2	(RK38R)
DIL Socket 14-pin		2	(BL18U)

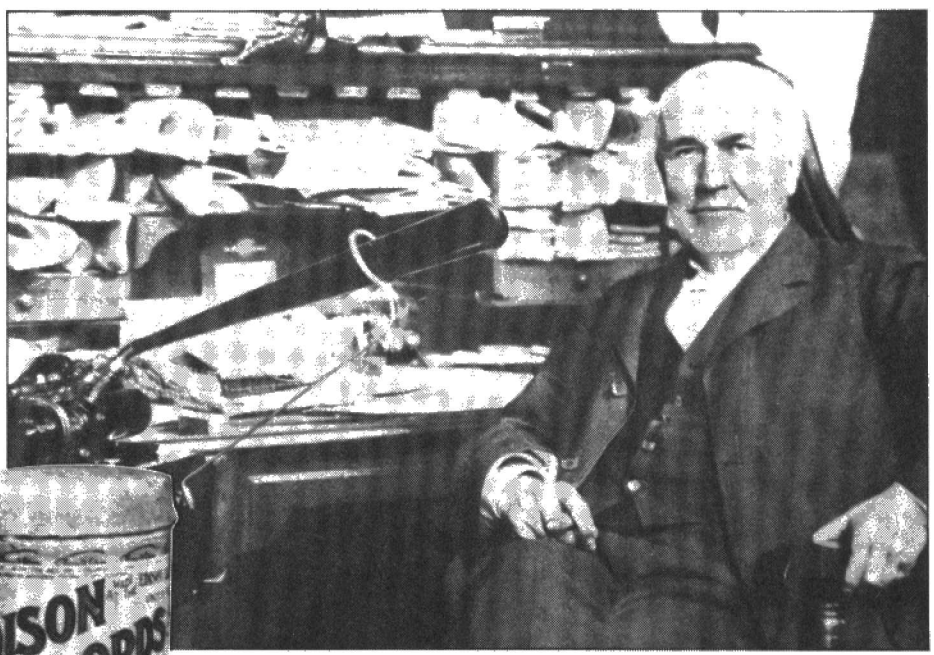
A Kit containing the parts listed above is available.
Order As LK59P (Mains Controller Kit) Price £8.95

The Mains Control PCB is available separately.
Order As GB77J (Mains Control PCB) Price £2.99

ELECTRONIC CHRONICLES

A Brief History of Electronics

by Mike Wharton Part 4



The 20th century has often been referred to as the Atomic Age, due mainly to the advances in nuclear physics which resulted in the production of the atom bomb. Although this has tended to dominate our lives since the Second World War, it could equally well be argued that the same period should be more correctly called the Electronic Age. The advances in the use and application of electronics has continued almost unbounded, particularly during the past twenty years or so. Many of the machines available now would have been undreamed of at the beginning of the century, but nevertheless their roots can be traced back to this time.

At the turn of the century much of the 'background' work had been done by various scientists, so that the infant subject of electronics stood poised to blossom and bear the fruit we know today. It is instructive to trace the development of some of the pieces of modern electronic equipment, and this we shall do in due course; firstly, though, there are a few interesting personalities from this period who deserve some attention.

EDISON

Thomas Alva Edison stands alongside Joseph Henry as one of America's greatest inventors. Indeed, it may be said that Edison invented the business of inventing things! Unlike many of his contemporaries he was not of an academic disposition, and much more interested in putting ideas to work to produce a saleable item. In this way he was very much heralding the pattern of working which can be seen today in the modern Research and Development departments run by large companies.

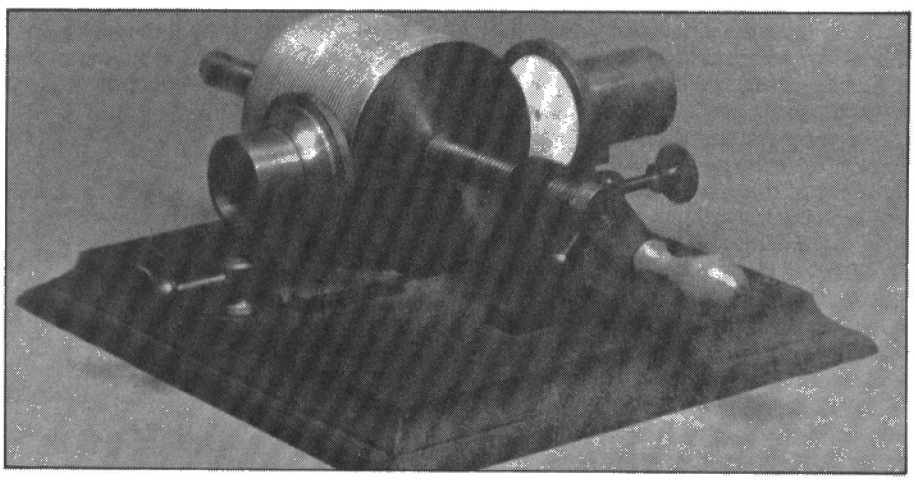
Edison was born at Milan, Ohio in 1847. He had a very ordinary education, but his curious way of asking questions was taken for queerness by his neighbours, and his school-teacher told his mother that he was 'addled'. This infuriated her so much that she took him out of school and attended to his education herself. He turned to books for an education, and devoured anything he could find, reading almost as quickly as he could turn the pages and remembering almost everything. When he began to read books on science he turned to experimenting in a small laboratory built in the house. In order to get money for chemicals he took on a job, at the age of twelve, as a newsboy on a train between Port Huron and Detroit, Michigan. During the time in Detroit he waited in the library, reading yet more books.

Selling newspapers wasn't enough for him, and he bought a second-hand press and began to publish a weekly newspaper of his own, probably the first to be printed on a train. With his earnings he set up a little chemical laboratory in the baggage car; unfortunately, a chemical fire started at one time, and he and his equipment were thrown off the train. In 1862, young Edison rescued a small boy on the railway tracks, and the grateful father offered to teach him telegraphy, since he had no money for a reward. Edison was keen to learn and soon became the best and reputedly the fastest telegrapher in the United States. He had also earned enough to buy a collection of the writings of Faraday which solidified his interest in electrical technology. In 1868 he went to Boston as a telegrapher and in that year patented his first invention. It was a device to record votes mechanically, for he thought it would speed matters in the American Congress and hence would be welcomed. It wasn't. A Congressman told him that there was no need to speed up the proceedings and that often a slow vote was a political necessity. After that Edison decided never to invent anything unless he was sure it was needed.

In 1869 he went to New York City to find employment. Whilst he was in a stock-broker's office waiting for an interview, the telegraph machine broke down.

Edison was the only one there who could mend it, and was promptly offered a better job than he had originally gone for. From this point his career really blossomed, and after a few months he decided to become a professional inventor. He had devised a ticker-tape machine during his stay in Wall Street, and offered it to the president of a large firm. He had wanted to ask $5,000 for his machine, but lacked the courage, so instead asked the president to make an offer. The offer was a staggering $40,000 and Edison, at the age of 23, was in business.

In 1876 he set up his research laboratory in Menlo Park, New Jersey. This was to be an 'inventions factory', and eventually he had as many as eighty competent scientists working for him. This was to be the fore-runner of the modern 'research team'. He hoped to be able to produce a new invention every ten days, and he didn't fall far short of his target. Before he died he had patented nearly 1,300 inventions, a record no other inventor has even approached.



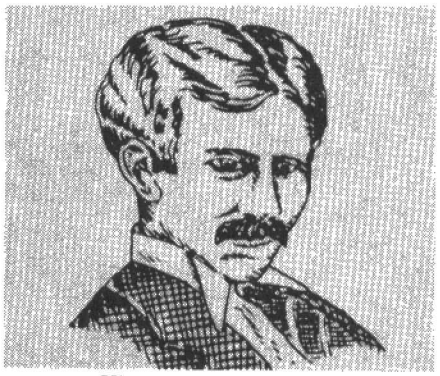
At Menlo Park in 1877 he invented his own favourite device, the phonograph. Although it has been much improved over the years, in the first place by Edison himself, the principal of operation remains unchanged over one hundred years later. With the invention of a machine that could talk, Edison finally convinced the world that he could do anything. Thus when he announced that he was to turn his attention to the production of an electric light bulb, the value of gas-light shares tumbled in both New York and London, so great was the faith in his abilities.

However, it seemed that he had bitten off more than he could chew, for he was not the first to fail in this quest. What he wanted was a wire that could be heated to incandescence without melting or oxidising in the rather poor vacuums possible at the time. For a while it seemed that he too would fail, for it took him $50,000 and a year of experimentation just to find that platinum wires would not work. After thousands of experiments he eventually discovered that a fine carbon fibre made from a scorched cotton thread was what he had been seeking, a solution which had been arrived at independently by Swan in this country. On October 21st 1879 he set up an electric bulb made with such a filament; it burned continuously for forty hours and became the subject of the American patent number 222898. On the next New Year's Eve the main street of Menlo Park was illuminated by electricity in a public demonstration that attracted three thousand people from New York to marvel at it.

There have since been many developments to bring the seemingly humble light bulb to its present state, and a tungsten alloy filament has long since replaced the scorched cotton. The advent of electric lighting brought with it many problems, some almost more intractable than the bulb itself. One such problem was to produce a generator whose output remained constant as lights were turned off and on, and Edison and his team tackled this with success. There was also the problem of power distribution, which was to bring him into sharp conflict with Tesla and reveal a less attractive side to his nature.

Over the remaining years of his life he was involved in all manner of inventions, but throughout scorned the analytical approach to problem solving; his method was to read everything on the subject and then try every possibility in an all-devouring attack from all sides. He often conquered by sheer weight of effort. When eight thousand attempts to devise a new storage battery had all failed he said, "at least we know eight thousand things that don't work!".

"Genius", he is reputed to have said, "is one percent inspiration and ninety-nine percent perspiration". This seems to have worked for him, but there are probably not that many scientists with Edison's capacity for perspiration. Edison did record one scientific discovery. In 1883, whilst working on improvements to the electric lamp, he sealed a metal wire into the bulb close to the hot filament. To his surprise a small current flowed from the hot filament to the wire across the gap. He duly wrote it up in his note-book, patented it in 1884, but since it seemed to have no practical use he didn't follow it up with his usual zeal. What he had described is called the Edison effect, & was of great importance in the design of the later electronic valves by Fleming & de Forest.



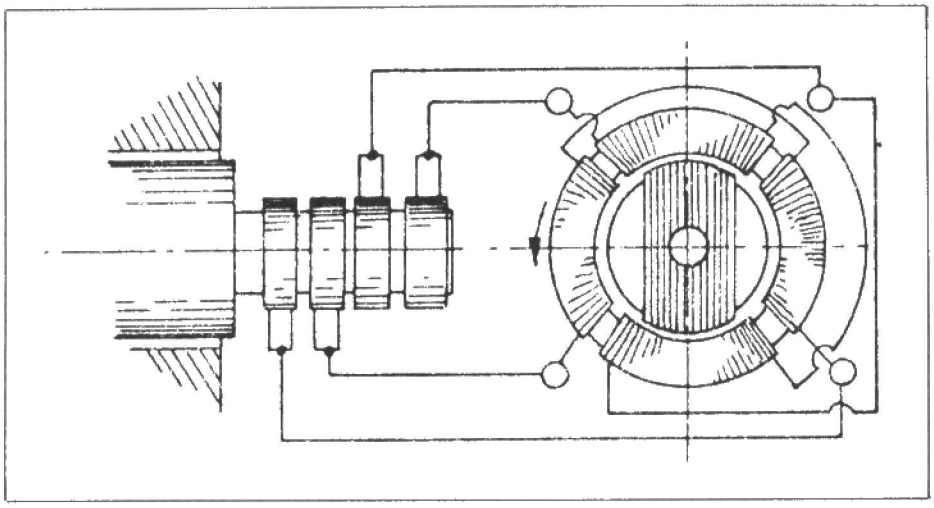
Nikola Tesla 1856-1943

TESLA

Nikola Tesla was born in 1856 in Smiljan, a town which was then in Croatia but is now in Yugoslavia. He studied engineering at the University of Graz, where he then began his inventing career. In 1884 he emigrated to America where he worked for a time for Edison, who had been his boy-hood hero. He worked long hours and developed a very successful arc light for street lighting. Unfortunately, being inexperienced in money matters he was exploited and soon became penniless. Edison went back on a promise to pay him for a particular invention, and Tesla left after a fight. This was the start of a long-running feud between the two men, for although Edison was regarded as having a dictatorial manner, Tesla was not the easiest of people to get on with. After this he worked as a labourer laying cables until he could raise enough money to start his own firm, the Tesla Electric Company.

He produced transformers for the generation of the high voltages for his AC power distribution system. In 1889 he accepted an offer to merge with the Westinghouse Electric Company, for which he was paid one million dollars and royalties of one dollar per horsepower developed by his AC motors. Working in his own laboratory he continued to produce many inventions, including the 'Tesla Coil', a high frequency air-cored transformer capable of producing sparks 5 metres long.

As an inventor Tesla was not in Edison's class (no one ever was), but he managed to do very well. His greatest claim to fame is that he made alternating current a practical possibility. One of the great problems standing in the way of the development of the electrical industry at the end of the nineteenth century was that of transporting electricity over wires without too much loss. It was found that electricity could be transported more efficiently at high voltages, since for the same power an increase in voltage allows a reduction in current, and the major loss is proportional to the square of the current; ($W = I^2R$). The current available from batteries or cells was, of course, DC, and no practical scheme for supplying Industry could ever be based on these, even if they were connected in series in order to obtain the required high voltage. Tesla's idea was to use step-up transformers fed with alternating current to



Tesla's first induction motor – 1887

raise the voltage for transmission, and then step-down transformers for the reverse process at the destination. One problem this produced in turn was that electric motors were then needed which would run on alternating current (AC), and Tesla also devised the induction motors that would operate on AC. This method of electric power distribution is now common-place, and the high-voltage transmission lines strung from their pylons and the attendant transformer sub-stations are familiar sights across many landscapes.

At this point, though, the superiority of this system was not proven, and Tesla and Edison emerged as the protagonists in an AC versus DC battle. For while Tesla had been working on AC, Edison had a vested interest in promoting DC power distribution. Edison's long career of always being right, and Tesla's own queer attitude made rational judgement virtually impossible. It is to Edison's dis-credit that he used some underhand methods to deter the use of AC. For example, he lobbied the authorities in New York to adopt the use of AC for its newly devised electric chair; indeed, AC is better than DC for electrocution. Having achieved this he then tried to point with great horror to the electric chair as an example of the deadly nature of AC! Tesla fought back with enduring bitterness, and enlisted the aid of inventor and business man George Westinghouse, and in the end the efficiency of AC won out over DC.

In 1912 there was the intention of awarding the Nobel Prize for Physics jointly to Tesla and Edison, but Tesla refused to be associated with Edison in any way and so the prize went to someone else. The last twenty-five years of Tesla's life degenerated into wild eccentricity. He became interested in the emergent subject of radio transmission, but Tesla's hope was to use it to transmit electrical power. Despite the expenditure of much effort and money this was to be an abject failure. Even so, his other achievements were great and the SI unit of magnetic flux density, (one weber per square metre), has been named the 'Tesla' (T) in his honour. He died in New York in 1943.

MARCONI

One cannot progress much further in discussing the famous men of electricity in the twentieth century without some reference to Guglielmo Marconi. For it was he who set the ball rolling for one of the main endeavours in electronics, that of wireless communication. Marconi was similar to Edison in one important respect; he was a practical man who acted and experimented first and then left others to explain why what he had achieved should be impossible!

Marconi was born into a well-to-do family in Bologna, Italy in 1874. He was privately tutored, but never entered a University. In 1894 he came across an article on electro-magnetic radiation, discovered eight years earlier by Hertz. It occurred to him that these could be used in signalling, in much the same way that messages were being sent by telegraph, but without the wires. He set up some apparatus along the same lines as Hertz, using a spark generator as the transmitter and a device called a coherer to detect the signal. The devices available for detecting such radio waves were very primitive and inefficient, for although it had been shown that the radiation produced had properties similar to light rays, Marconi was still working in the dark, so to speak. A coherer was a glass tube loosely packed with iron filings, which normally only conducted a small current. When the radio waves fell upon it the conductivity increased and the current rose. In this crude way the radio waves were converted into a detectable current. By today's standards these transmissions were very simple, for the radiation would have covered a broad band of frequencies, more akin to heavy interference. Also the receiver was very insensitive, since no form of 'tuning' had been thought of yet. Gradually, though, he improved his instruments, grounding both the transmitter and receiver, and using a wire insulated from the earth to act as an aerial or antenna to improve sending and receiving. As time went by he sent signals over greater and greater distances; in 1895 he sent one from his house to the garden, and later over a distance of one mile.

The Italian government showed little interest in his work, and so in search of greater sponsorship he moved to this country in 1896. Here he managed to send over a distance of nine miles, and

Continued on page 42.

Marconi Company Ltd.

Marconi with his apparatus for 'telegraphy without wires' – 1896

Marconi Company Ltd.

MEASUREMENTS IN ELECTRONICS

By Graham Dixey C.Eng., M.I.E.R.E. Part Five

Introduction

In the practice of electronics, the techniques of measurement and testing perform a variety of roles. They may be used in the design and development of original equipment (as opposed to existing equipment) to evaluate the design as work proceeds. In the design of an amplifier, for example, this will involve d.c. measurements to establish that the bias conditions are as required; also a.c. tests to measure terminal impedances, gain, bandwidth and any other special requirements. This is as true in a hobby situation as in the laboratories of some industrial giant.

On the production line, measurement and testing are vital for setting up and testing to specification equipment in manufacture. Depending upon the nature of the equipment, type of test and perhaps, the size of the company, such testing may vary from manual procedures right through to fully automatic testing, computer controlled.

What may be considered as a rather less romantic area of testing is electronic servicing, i.e. the testing of existing equipment either to ensure that it continues to function well or to rectify a fault when one occurs. It is, however, a challenging aspect of electronics and one which employs a large number of engineers, technicians and mechanics, certainly far more than are ever employed in development laboratories. It is really detective work of electronics and there is perhaps something of the same satisfaction at the moment that the culprit (the defective component) is apprehended.

In this, the penultimate part of this series, we shall consider the latter category of electronic measurement and test. In the final part we shall look at the evaluation of circuits in the laboratory. Production line testing we shall omit as it is usually of little interest to the hobbyist.

Logical Approach to Fault Location

It is actually possible to find some faults by opening up the set, peering inside and pushing and pulling everything in sight! However, if this is the limit of logic in your approach, most faults will elude you. On the other hand, it is not necessary to have at hand a vast range of expensive instruments. Many faults can

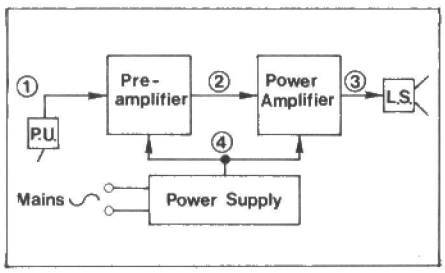


Figure 1. Schematic of simple record player

be found with nothing more than a multimeter and knowledge of how the particular piece of equipment operates. It is possible to formalise the procedure by adopting a specific routine. Examples are the 'end-to-end' and 'half-split' methods. The former is the means that many people would use without actually calling it by that name.

Assuming that the record player of Figure 1 produced no output, how would the faulty area be found? There are four labelled test points. To some extent the choice of the first test point to go to is dictated by the precise nature of the fault. 'No output' might actually mean 'no signal output', a 'hiss' being heard in the loudspeaker; in this case it is probably a safe bet that there is no problem with the power supply. If, however, no output means just that, then it is more logical to check the power supply and mains input first. Let us assume the first case, i.e. loss of signal and compare the methods named in order to identify the faulty area.

First the end-to-end method. There are two approaches to this. Either inject a signal from a test instrument into each test point in turn (1; 2; 3 or 3; 2; 1) and note when an output is heard; or use a record disc as the signal input and connect an indicator (high impedance type) to each test point and note when a reading is obtained. The former is usually more

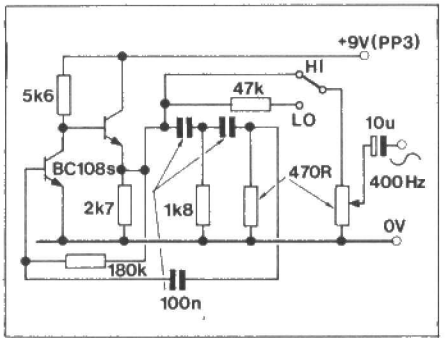


Figure 2. A variable output level signal injector

convenient, as a simple audio signal injector can be cheaply made and conveniently included in one's tool kit (not all servicing work can be done in the convenience of one's workshop). A design for a simple audio signal injector is given in Figure 2. To cope with a range of signal levels, a fixed/continuously variable attenuator is included. Excluding case, it can be built for about £2.00. Assuming that a signal injected at test point 1 produces no output but a signal injected into test point 2 does, then clearly the fault lies somewhere in the pre-amplifier.

It is useful to compare this with the 'half-split method', the object of which is to eliminate as much as possible each time a test is made. (The end-to-end method eliminates only one item at a time). Thus, in the half-split method the signal is first injected into test point 2. If, for example, this gives no output then the fault lies in the second half of the circuit; otherwise the first half is faulty. Assuming the first possibility, the signal is injected into test point 3 thus eliminating half of the remaining components. Each successive test always eliminates half of the suspect stages. This may seem a trivial illustration and in a simple example like this there is little merit in using this method as compared with any other. But where it is an advantage is where there are a large number of stages (or components) in series. Suppose, for example, there are 40 items in series. In the end-to-end method the faulty item may be found at the first test or the 40th. But in the half-split method, the number of items eliminated in successive tests is: 20; 10; 5; 3 (or 2); 2 (or 1); 1, i.e. no more than six tests. Thus, the merit of the method is speed. Some people may consider this discussion a little academic but what it should highlight is the benefit that can be gained by a careful and systematic approach to the subject.

Parallel Chains

There are a number of circuits that produce several outputs which may or may not be related. Common examples are stereo systems (separate left and right audio outputs) and TV receivers (separate sound and vision outputs). Invariably there is some common area and it is this area that must be investigated when all outputs are affected simultaneously. Conversely, it is this area

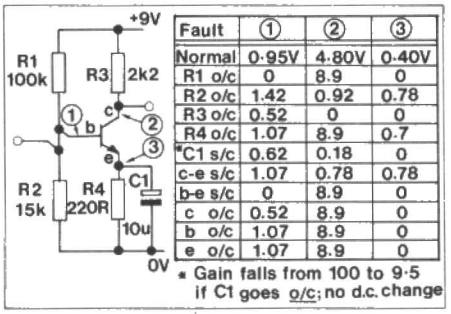
that can be ignored if not all outputs are affected. It is usually easier to find a fault in the common area than in specific areas. Sometimes it is as simple as a blown fuse or a loose mains connection. Otherwise the series methods must be employed for the defective chain. Sometimes, as in the case of a TV receiver, waveforms and voltage levels for correct operation are available so that a meter or CRO can be moved along the chain to pinpoint the defective stage. In this case the signal received via the aerial is the test signal.

Fault Location at Component Level

Having narrowed down the fault to a specific stage of the equipment, there still remains the problem of finding the defective component. I must use the word component loosely for sometimes the fault will be found to be a dry soldered joint, a crack in a PCB track, an ill-fitting pin in a socket, etc. Faults of these kinds often evidence themselves by slightly flexing the PCB and may need quite a bit of patience in finding. Sometimes a component fails catastrophically, such as when a resistor overheats due to a 'short' somewhere. It reveals itself by its discolouration. But most times the failed component just sits there, looking no different from its neighbours. So this is where the real detective work comes in.

Some components fail in characteristic ways. For example resistors invariably go high resistance or open-circuit though there are instances where the opposite has occurred. Capacitors may fail open or short-circuit. Semiconductors may fail with short-circuit junctions or open-circuit internal connections. There are some common failures that lead to recognisable results. Figure 3 shows an amplifier together with a tabulation of the way in which the d.c. potentials at collector, base and emitter are affected by listed component failures. Convince yourself that you agree with these results. The principles involved are very simple. For example, if the bias resistor R1 becomes open-circuit, clearly there is no base drive, hence no collector current and no volt drop across either R3 or R4. Thus, the collector and emitter potentials measure as +9V and 0V respectively. On the other hand, R2 becoming open-circuit means that there will be too much base drive, the transistor will saturate and the collector and emitter potentials are very similar. The only component failure in this stage that doesn't cause any change in the d.c. levels is where C1 becomes open-circuit. What this does is to introduce a substantial amount of negative feedback which will reduce the gain of the stage. When a loss of gain occurs without distortion it is worth checking the emitter bypass capacitor by bridging it with a similar type; restoration of normal gain indicates a faulty capacitor.

The evidence of a fault in an amplifier is usually a change in the 'signal', e.g.



Fault	①	②	③
Normal	0·95V	4·80V	0·40V
R1 o/c	0	8·9	0
R2 o/c	1.42	0.92	0.78
R3 o/c	0.52	0	0
R4 o/c	1.07	8.9	0·7
*C1 s/c	0.62	0.18	0
c-e s/c	1.07	0.78	0.78
b-e s/c	0	8.9	0
c o/c	0.52	8.9	0
b o/c	1.07	8.9	0
e o/c	1.07	8.9	0

* Gain falls from 100 to 9·5 if C1 goes o/c; no d.c. change

Figure 3. Effects of common amplifier faults

complete loss, gross distortion, reduced gain without distortion, etc. But the method used to identify the faulty component is usually a DC one, by measuring the DC potentials and deducing exactly *why* they are wrong.

Among the questions that may arise in this sort of work is how to deal with integrated circuits, essentially a single component though a very complex one. The best way is to regard the IC as a sub-system and test it as such. That is, check d.c. supplies to the chip, check signal (or logic) levels at pins. If an incorrect level is found the possibilities are either an internal chip fault or a fault in, say, a discrete component connected to that pin. Check the discrete components first, then the IC by substitution. The latter can be a nuisance if soldered straight into the PCB. A desoldering tool will be needed to free the pins. It may be a good idea to solder an IC socket into the board and plug the substitute IC into this. It makes life easier if there is a recurrence of the failure. Remember the advice given in Part 4 of this series when measuring voltages on IC pins. Measure directly on the pins not the PCB tracks; this eliminates breaks in the latter.

Some Practical Examples

The serviceman should develop a logical approach from the start and record everything he finds for future reference. Ability is acquired by experience provided that one learns from it. There is no 'magic formula' for finding a fault; just a general approach to the task. It is worth looking at several quite different circuits to see the effects of faults on them. Apart from anything else, it will be a useful intellectual (but still practical) exercise.

Audio Power Amplifier

In keeping with what was said earlier about knowing how the circuit worked, we start with a brief description of the circuit shown in Figure 4. Transistors Q3/Q4 form a complementary/symmetry pair driving the 8 ohms load through capacitor C6. Q2 is the driver transistor with collector load R9. RV1/R8 are used to eliminate cross-over distortion. Q1 is the pre-amplifier with base-bias provided by the chain R1/R2/R3. The amplifier is d.c. coupled with a d.c. negative feedback loop completed by R4. An a.c. negative feedback loop is completed through the same resistor and C3, the amount of N.F.B. being determined by the relative values of R2 and R3; but the N.F.B. increases at h.f. due to C4. The collector load of Q1 is R5. R7 and C2 provide supply decoupling, C1 is the input d.c. blocking/signal coupling capacitor of course and R6 and C5 are the usual emitter components for Q2. So now for some faults, with solutions later.

(a) The amplifier is unstable and oscillates continuously; clearly the gain is far too high.
(b) The gain is only about half what it should be; but there is no distortion and d.c. conditions are correct.
(c) There is no output signal at all; however measurements with a multimeter show that all d.c. potentials are normal.
(d) There is no output signal and d.c. measurement of the mid-point voltage shows that it is at +9V (i.e. supply voltage).
(e) There is a distorted output and d.c. measurement of the mid-point voltage shows that it is at +1.7V only.

TTL Pulse Generator

This is a simple variable frequency, variable pulse width generator, which is shown in somewhat simplified form in Figure 5. It works as follows:

Assume that the output of G3 is at this

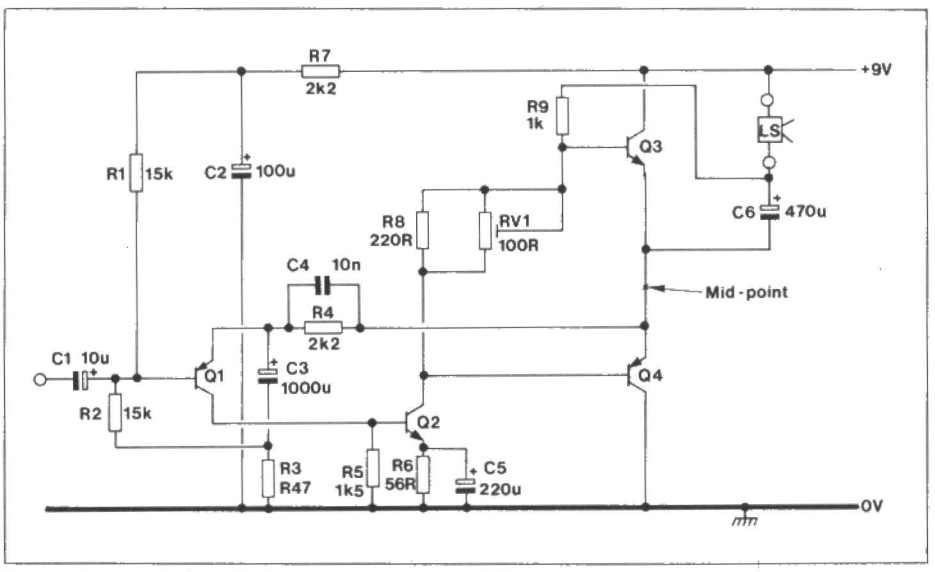


Figure 4. A typical audio-frequency power amplifier

instant logic 1. Then the output of G1 is logic 0 and the output of G2 is logic 1. The R1/C1 combination between G2 input and output controls the frequency of the pulses and current now flows in this series path. After a time determined by the values of R1 and C1 this charging current is almost zero and the input to G3 is then at logic 1. Its output must then swing to logic 0 causing G1 output to go to logic 1 and G2 output to logic 0; in other words a reversal of potentials around the loop and a reverse charging current through C1. At the end of this charging time the input to G3 has returned to logic 0 and its output to logic 1, thus completing one whole cycle.

After this a short zero-going pulse is produced once a cycle by G4 and its input time-constant R2/C2, and this triggers the 74121 monostable to give an output pulse of defined width. The R3/C3 combination, selected by switching determines this width. The monostable gives two complementary outputs at pins 1 and 6, the 'normal' output being on the latter. As with most generator circuits, a fault often 'kills' the oscillation, so that the symptom tends to be the same for a variety of faults, i.e. no output. Thus the symptom may give no real clue and other indications must be looked for. An obvious first question for any multi-range instrument is 'has it failed on *all* ranges?', because a failure on one range only, will pin-point the faulty component straightaway in most cases. But assuming that all ranges are equally affected, it is necessary to work through stage by stage, looking for anomalies. This time the faults are presented in tabular form (see Table 1).

Only a logic probe was used initially to establish the logic levels. This can be followed by the logic pulser and substitution checks.

SCR Power Control

In Figure 6, SCR1 is the main SCR which controls conduction in the load.

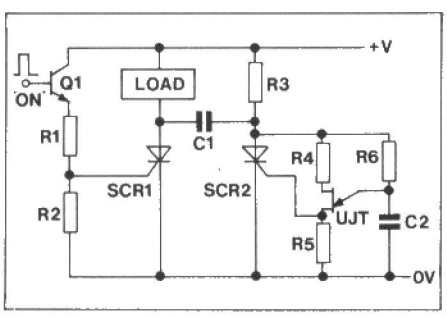


Figure 6. SCR power control circuit

Conduction is initiated by switching on Q1 with an input pulse. With SCR1 off, SCR2 is normally on so that its anode voltage is very low. Consequently C1 charges to a potential V, the right-hand plate being negative. Also the low anode potential of SCR2 disables the UJT relaxation oscillator. When SCR1 is triggered on by a pulse, its anode potential drops to a very low value and the voltage on C1 reverse-biases SCR2 switching it off and allowing the UJT oscillator to run. The polarity of the voltage on C1 now reverses so that, when the UJT fires SCR2 into conduction, C1's left-hand plate has a negative potential and this reverse-biases SCR1 so turning it off. The time delay between SCR1 being triggered on and then turning off automatically is determined by the time constant R6/C2.

There are several faults possible on such a circuit which will result in under or over-controlling the load power. For example:

(a) Load is energised continuously, even with no 'on' pulse.
(b) Load is energised correctly but fails to turn off.
(c) Load fails to turn on.

Each of these can be caused by a number of different component failures.

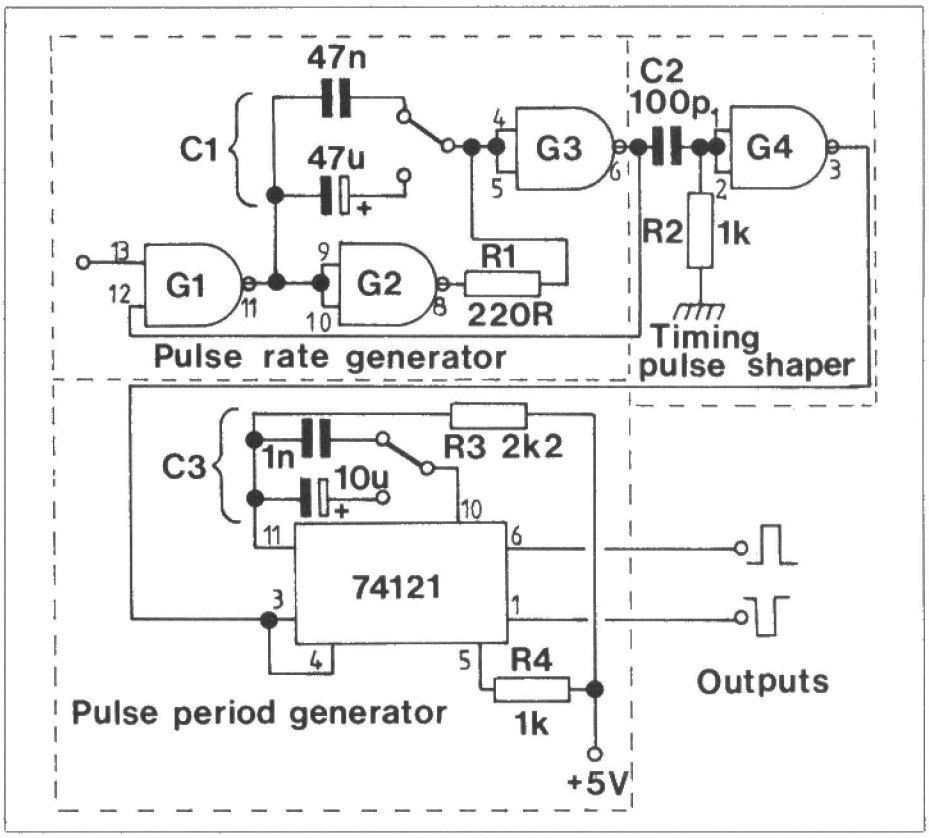


Figure 5. A TTL pulse generator

Fault Symptom	G1	G2	G3	G4	74121 (pin 6)
(a)	1	0	1	1	0
(b) No Output	1	0	0	1	0
(c)	pulsing	pulsing	pulsing	1	0

Table 1. Logic Levels At Gate Outputs

Discussion of the Faults

Perhaps in reading through the foregoing you may have formed some conclusions as to what could cause the symptoms on these three representative circuits. If so, now is the time to compare notes and see how our detective work agrees.

Audio Power Amplifier

(a) If the amplifier is unstable, the N.F.B. loop is almost certainly open. The loop is closed by three components: R4, C3 and R2. Both resistors, if open circuit, would also affect the d.c. conditions. This is not the case; therefore C3 is the logical choice.
(b) The faulty component is almost certainly C5 (open-circuit). As mentioned before, this invariably is the fault when there is loss of gain without distortion.
(c) In a d.c. coupled amplifier most component faults cause a change in d.c. conditions. When there is complete loss of signal and the d.c. conditions are correct, look for an open-circuit component in series with the signal, e.g. C1, C6, load connections.
(d) In this case the lack of output signal is caused by the output (mid-point) being firmly held at supply voltage. Therefore the fault is a d.c. one and there are several possibilities, but one of two conditions must be true: either Q3 is short circuit or conducting hard. If the latter is true, then the collector potential of Q2 must be high, i.e. Q2 is at or near cut-off. Check bias condition on Q2. Is base lead open? Is there a base-emitter short?... etc.
(e) This is the opposite situation in which the mid-point is very low in potential, but not low enough for Q4 to be short-circuit. Note therefore, Q4 must be conducting heavily, which means either Q2 is short-circuit or conducting hard. The conduction of Q2 depends upon that of Q1 (one of the complications of d.c. coupled amplifiers!). For example, R1 might be open-circuit, C1 might be short-circuit. Further poss-

ibilities are that R7 is open-circuit or C2 is short-circuit, since these faults would deprive Q1 base of the return path to +9V (remember that this is a PNP transistor).

TTL Pulse Generator

(a) Obviously the pulse rate generator is not oscillating. Each NAND inverter is actually inverting its input level. Suspect the feedback path R1/C1. OK? Time for the logic pulser. The most obvious point to try is pin 13 of G1. Since pin 12 is at logic 1 then, if pin 13 is pulsed to logic 1 also, a probe on pin 11 (G1 output) will momentarily show logic 0. If not, suspect and check short to 0V (internal or external to chip) from pin 13.

(b) What is immediately obvious about the logic levels with this fault is that for both gates G2 and G3 the output is not being inverted by G3 (G3 faulty) or it is not reaching G3 (R1 open). Both of these can be readily checked.

(c) In this case the logic probe shows that the pulse rate generator is running. Therefore, either the monostable is faulty or it is not receiving its drive. It is a series chain so look for a break. The pulse is present up to the output of G3 then disappears. Try bridging C2 with a similar capacitor; otherwise check for track breaks, G3 to C2; C2 to G4.

SCR Power Control

(a) There is really not a lot of choice here. SCR1 is independent of the 'on' pulse to Q1. In other words, it is already getting its drive (Q1 collector-emitter short-circuit) or SCR1 is actually shorted. Remove each in turn and check.

(b) There are more possibilities here. Is C1 open? Check by bridging. Is SCR2 on or off? Check with d.c. voltmeter. Is UJT running? A d.c. voltmeter across C2 should show a rising voltage. These checks lead to other checks, as in all good detective work.

(c) This implies lack of drive to the gate of SCR1. Check wiring from input point ('on' pulse) to SCR1 gate. Then, is there an internal open circuit in Q1? Try a 'croc-clip link' from top of R1 to +V. Does SCR1 come on now? If yes, replace Q1; if no, check R1.

The above circuits are only three of many that could have been chosen to illustrate these discussions. Hopefully, they are sufficiently different to have had the most value. What they should have shown are the mental processes and test techniques involved in tracking down faults in modern electronic equipment.

In the next and final part of this series, we shall examine the ways in which we can measure the performance of electronic equipment in the laboratory.

ELECTRONIC CHRONICLES *Continued from page 38.*

succeeded in obtaining a patent, the first in the history of radio. The following year he sent signals twelve miles and then eighteen miles to a warship out at sea. By this time he was just beginning to make the system a commercial proposition, and Lord Kelvin sent a Marconigram to his old colleague Stokes. In 1900 he obtained a key patent, (number 7777) and then in 1901 he was set to make his historic transmission. Despite the fact that radio waves, like light waves, travel in straight lines, Marconi was sure that they would follow the curvature of the Earth. Thus he set about to transmit across the Atlantic, which he achieved on December 12th 1901, from Poldhu in Cornwall to Newfoundland. It was left to others to explain why this apparently impossible feat had worked, due of course to the reflecting layers in the ionosphere. Also, these transmissions were only in Morse Code, and it was some time before the techniques of radio communication had been developed to a sufficient standard for broadcasting.

In 1909 he shared the Nobel Prize for Physics with a German by the name of Braun, whom we shall encounter again later. The Italians eventually recognised his contribution to science, and bestowed the title of 'Marchese' on him in 1929. He died in 1937, in Rome, and was given a state funeral by the Italian government.

RADIO

From this point on the number of people involved in the development of the wide variety of inventions and discoveries related to electronics becomes almost too many to mention individually. Pretty well any piece of present day equipment is the result of combined efforts over many years by a veritable army of unsung heroes, each contributing some small piece to the final picture. To complete this article we shall end by looking at the way in which one invention, Radio, has been developed.

Marconi's first efforts around the turn of the century were just the beginning of this multi-million pound industry. The spark-gap transmitter used was simple, but yet surprisingly effective. More importantly, the receivers were very crude, since as yet the idea of tuned transmission had not been thought of, nor become necessary. The sensitivity of the receiver was crucial to the overall performance of the system, since no form of amplification was yet available. Many forms of 'dectector' were tried, and most of these owed more to rule of thumb 'hit-or-miss' methods than to a scientific understanding of the problem. Early forms of detector were the coherer, mentioned earlier, and also the 'cats whisker'. It had been shown by Braun, also mentioned above, in 1874 that some naturally occurring crystals allowed a current to flow more easily in one direction than another. Such a set up can convert the AC of the receiver signal into a more easily detectable DC.

One of the next improvements came about as the result of one of Edison's observations, that of the so-called Edison effect. It was the English scientist Ambrose Fleming who further examined the nature of this effect, and realised that it was due to the newly discovered electrons boiling off the hot filament and being attracted to the plate or anode. He called it a valve, since it allowed current to flow only in one direction, so that like the crystal rectifier an alternating current produced a direct current output.

The next step along the way came in 1906, when the American, Lee De Forest, investigated the effect of inserting a third electrode between the anode and cathode. This produced a device whereby a weak signal applied to this electrode, called the grid, could control the passage of electrons between anode and cathode. The net result was the first amplifying device, and from here on all manner of possibilities opened up. Hertz had shown some twenty years earlier that the discharge from a capacitor was of an oscillatory nature, and the triode valve of De Forest could now be used to sustain these oscillations to produce a signal with a fixed frequency. However, the signals sent by such means were still restricted to the dots and dashes of the Morse Code, produced by interrupting the carrier wave. It was a Canadian/American physicist called Fessenden who devised the idea of 'modulating' the carrier wave so that normal speech and music could be transmitted. Fessenden has been overshadowed by his erstwhile employer, Edison, but he may be rated only second to him in the number of inventions he patented during his lifetime.

Another aspect of modern radio communication which is now taken for granted is the use of an antenna. In the early days it was not apparent that such a device would have any effect, even though it may only have been a long piece of wire. The credit goes to a Russian, Popov, experimenting with radio equipment at about the same time as Marconi, who was the first to use an antenna in sending signals from shore to the Russian Navy three miles out at sea. For this reason, the Russians claim it was Popov and not Marconi who should be credited with the invention of wireless communication.

During the intervening years further improvements were made, from better valves with more electrodes like the tetrode and pentode. In 1947 the wheel came virtually full circle with the advent of the transistor. This device relies upon the electrical features of certain crystals originally investigated by Braun, but now with much enhanced properties. Next time we shall trace the development of another modern miracle of electrical technology, television, and the people who have made it the success it is today.

LOW POWER RADIO CONTROL SYSTEM

★ **27MHz Operation For Ground-Based Model Control**
★ **Two Positive Pulse PWM Channels**
★ **Two Digital On/Off Channels**

by Dave Goodman

Since 1981 and the legalising of Citizens Band Radio on 27MHz, the licensing requirement for model radio control is no longer operative. However, certain conditions apply to both users of this band, and for RC modellers this means that signal transmissions must be within the frequency range 26.96MHz to 27.28MHz at a maximum mean power of 1.5W. Higher frequencies on this band are used for CB transmissions. The 35MHz band (35.005 to 35.205) is also available for radio control, but for use with model aircraft only – not ground-based models, and the 458MHz band would be complex for constructors to set up and align. Therefore a 27MHz system is used with limited power output and receiver sensitivity to avoid interference both to and from other users on the band.

Transmitter

The simple transmitter design of Figure 1, centres on IC1 which basically consists of three sections namely: frame and pulse timing; logic encoding and modulation; RF and output stage. Although capable of six channel operation the design utilises two channels (1 and 2) for pulse width modulation (PWM) and four channels for encoded digital (on/off) information. A train of six pulses (Figure 3) is generated every 20ms (50Hz) from the frame timer, C5 and R4 and 4.6V reference supply at IC1 pin 4. C5 is allowed to alternately charge and discharge by an internal comparator switch to generate the 20ms frame which starts the pulse timer C6 and R1 at IC1 pin 8.

The internal encoder provides six discharge paths for C6 at IC1 pins 18, 17, 16, 1, 2, and 3 – R2 providing a fixed time constant for channels 3 to 6 (pins 1 and 16 to 18) and RV1 and RV2 variable time constant for channels 3 to 6 (pins 1 and 16 to 18) and VR1 and VR2 variable time constants for channels 1 and 2. The serial pulse output from the encoder appears at pin 12 where C8 modulation filter capacitor is added to improve the transmitted carrier bandwidth. This is desirable where adjacent carrier channels are 10 to 15kHz apart instead of the more usual 50kHz separation. From IC1 pin 13, an internal emitter follower buffers the pin 12 modulation signal and supplies the collector of an internal NPN transistor at pin 11. IC1 pin 10 is the base connection for this transistor and drive current is supplied by R5. X1 is a third overtone crystal connected between base pin 10 and tuned circuit C10, C11, and L1 primary.

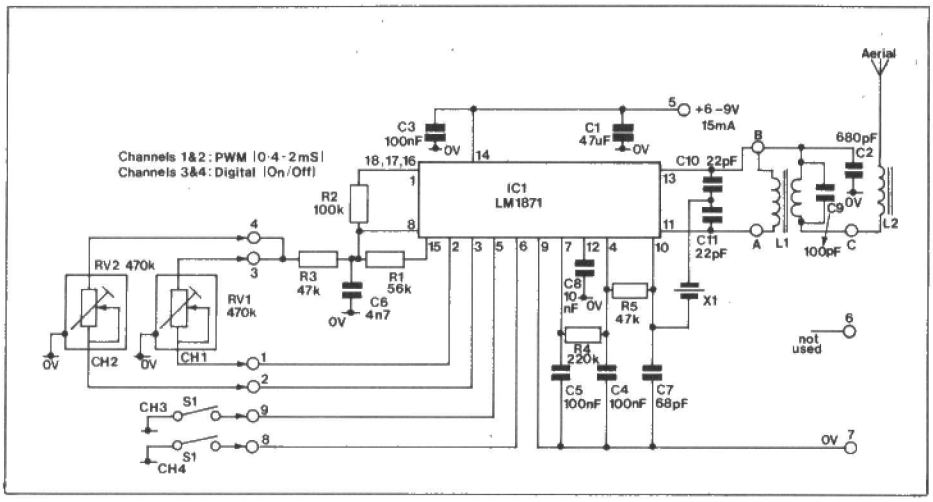


Figure 1. 27MHz Transmitter circuit diagram

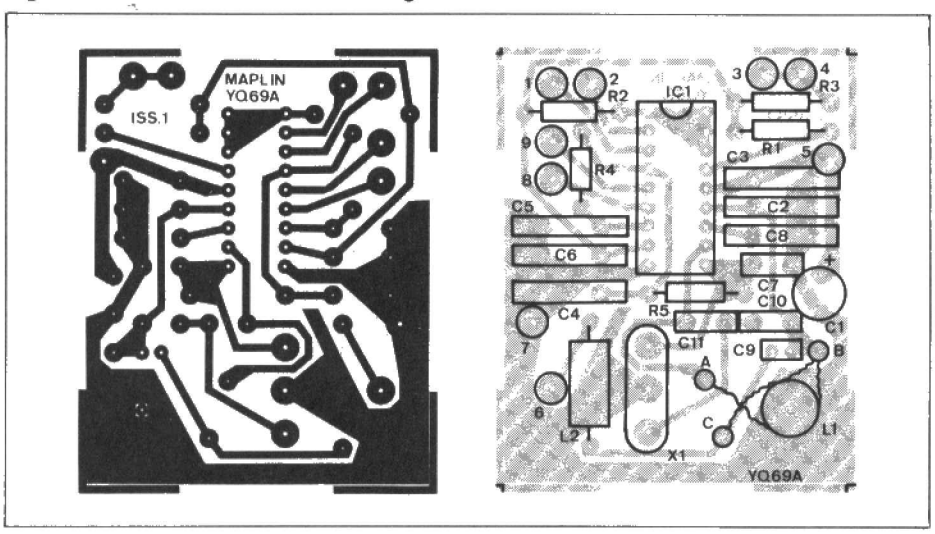
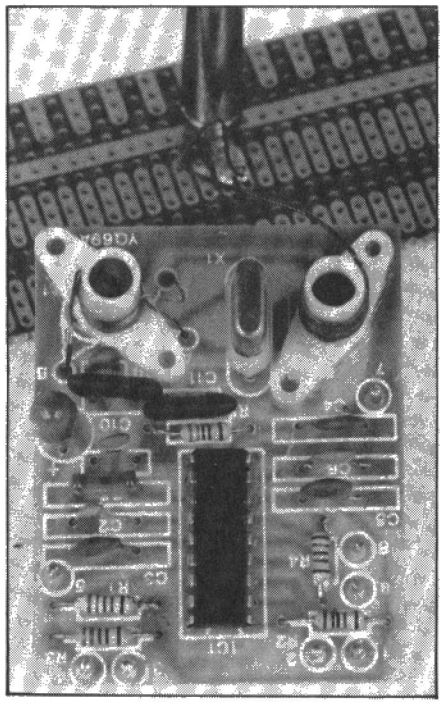


Figure 2. Track layout and overlay of Transmitter PCB

When the modulation output is high (+3.8V) at pin 13, the collector pin 11 and tuned circuit are pulled up into the active range of the internal transistor. RF feedback is via the crystal and pin 10, causing the tuned circuit to resonate at the desired frequency. Because third overtone crystals are used in this application a tuned collector load must be used to guarantee operation at the correct frequency. Tuning L1 by moving its dust core in and out of the former has very little effect on oscillator frequency, but does vary the angle of conduction and hence oscillator efficiency and harmonic suppression.

C3 and L1 secondary are also tuned to 27MHz and dust core adjustment determines coupling between both coils. For precise PWM detection it is necessary to produce a high on/off ratio when modulating the carrier. When modulation from pin 13 is low, crystal X1 continues to oscillate for some 500μs due to the high Q characteristics of the circuit. This 'ringing-on' would reduce the carrier modulation depth and C7 damps the crystal during this time; short carrier off times also help overcome this problem, but require X1 to be isolated from the aerial circuit, hence the split tuning capacitors C10 and C11. L2 further low-pass filters the transmitted carrier, thus reducing upper harmonic content and doubles as a base loading coil for the aerial.



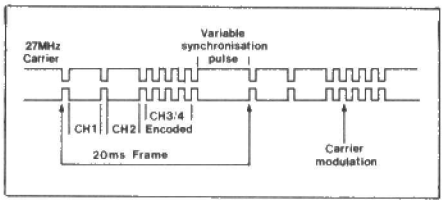


Figure 3. Transmitter envelope

Aerials

When calculating wavelength for 27MHz, the optimum aerial length is approximately 17ft. – hardly practical for a hand-held portable transmitter! Aerials of half, quarter, or sixteenth wavelength are far more practical, these being some 8½ft., 4ft., and 2ft. in length, but do not radiate as efficiently. A dipole system could be used, where a telescopic aerial is connected to L2 and an equal length of wire connected to 0V is left to hang towards ground. The aerial's capacitance would change as the wire is moved and transmissions become irregular so either centre or base loading of the aerial becomes desirable. Centre loading requires a telescopic aerial to be centrally cut and a coil inserted between both halves, whereas base loading, although not as efficient, does allow the impedance of the load at the feed point of the RF output stage to be adjusted, thus improving signal strength. With the output stage components as Figure 1, distances of 50 to 100 yards are possible depending upon terrain or surroundings.

Construction

Refer to the overlay and Figure 6. Pin 6 on the overlay is not used, as L2 fits over this position. Identify and insert resistors R1 to R5. Next insert capacitors C1 to C11. C1 is polarised and its + lead must align with the legend. C10 and C11 are a little large and will require being offset slightly to facilitate fitting. Ensure these components are pushed down as close as possible to the PCB. Solder all leads and cut off excess wire ends. Insert the crystal holder and IC1. Pin 1 is immediately below the circular indentation close to one corner of the package. Insert Veropins 1 to 5 and 7 to 9 and solder these and all remaining components.

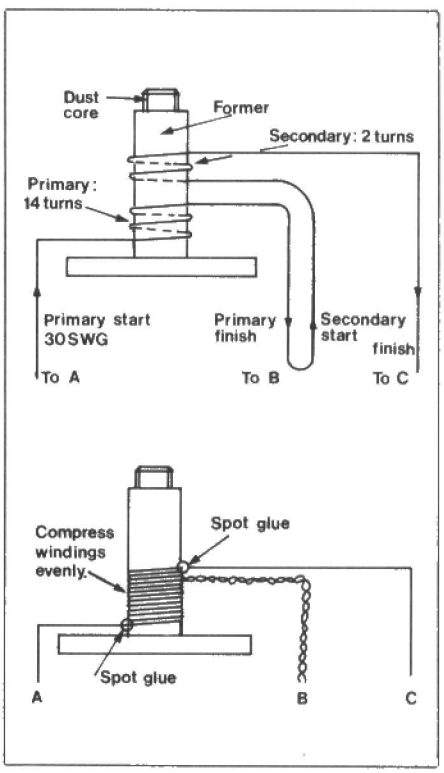
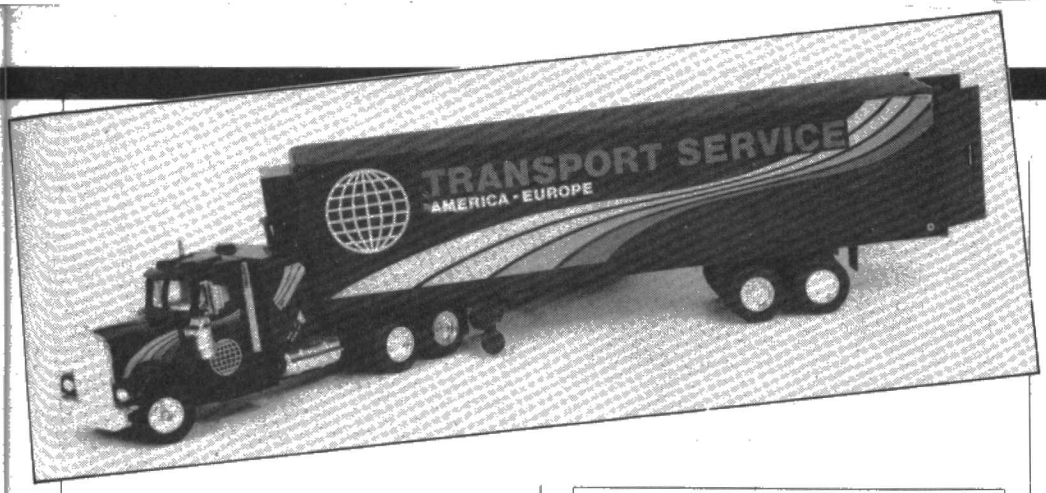


Figure 4. Winding details for coil L1



Good, accurate soldering is required if problems are to be avoided and cleaning the back face with thinners will help when inspecting the work.

Coil Winding (L1)

Both L1 and L2 have to be wound by hand. Although this may appear a daunting task, it is really not that difficult. For L1 you will need 1 metre (3ft.) of 30swg enamelled copper wire, a 7mm former and dust core and a tube of fast drying glue such as cyanoacrylate. Before construction examine Figure 4 to familiarise yourself with the turns requirements.

Primary winding A is begun at the base and fourteen complete turns wound up the tube. It does not matter which direction is chosen to wind the coil as long as both primary and secondary turns are in the same direction. It may be helpful to use the former's base mounting holes as wire anchor points when starting and finishing the coil as this will prevent the wire from unwinding until firmly glued. Once you have wound the primary coil, compress the windings together as shown and take up any slack by pulling the loose ends tight.

Apply a small amount of glue to the beginning and end of the coil and leave to harden. The finish wire from L1 primary is also the start for L1 secondary and allowance must be made for connecting it to to point B on the PCB by looping the wire out a few inches. Continue winding up the tube in the same direction as before for two complete turns. There should now be two single wire ends (A & C) and a double wire (B) extending from the coil. Again, apply spots of glue to both start and end windings of L1 secondary and leave to harden.

Coil Winding (L2)

For L2 you will need 1 metre (3ft.) of 24swg enamelled copper wire and a 7mm former with dust core. Winding procedure is similar to L1 except that a single coil of 12 turns is wound up the tube starting 2mm from the base as shown in Figure 5. Because this wire is thicker, it will be necessary to remove any kinks by gently stretching the length before winding, else the coil will be difficult to compress neatly. The 2mm gap is not critical and the coil could be wound centrally along the tube if desired. A small allowance should be made though for tuning purposes. Glue the start and end windings as before and leave to harden.

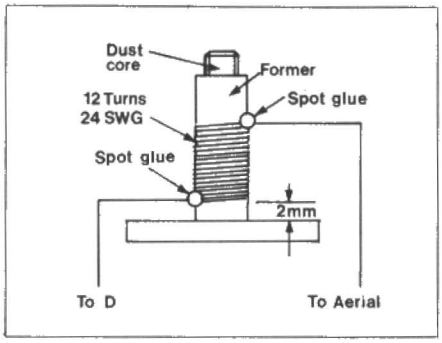


Figure 5. Winding details for coil L2

Mounting L1 & L2

Space is rather limited on the PCB, therefore both coils are mounted diagonally inwards from the right-hand corners as shown in Figure 6. Apply glue to each former base and stick the assembly in position.When mounting L1, be careful not to cover holes A and C and for L2 keep hole D clear. Leave both to harden before inserting the dust cores in case excess glue jams the threads. Insert a wire nearest to the base of L2 into hole D, then scrape off the enamel coating and tin with a soldering iron before soldering to the pad. On L1, insert the centre double wire into hole B, the primary start wire nearest the former base into hole A and the secondary finish, or topmost wire, into hole C. Each wire length from coil to terminating point should be kept short and direct otherwise tuning may be affected. When soldering these connections, heat the wire close to its pad and apply solder. The enamel will melt allowing contact with the copper to be made, then solder in place. Finally remove excess wire ends and fit crystal X1.

Choice of Crystal

Table 1 lists six available channel frequencies. These crystals come as Tx/Rx (Transmit/Receive) pairs and the frequency is stamped on the body of each one. Choose the channel to be used and insert a crystal marked with the higher frequency into the socket on the transmitter PCB. The lower frequency fits into the receiver which is explained later.

Channel	Transmit frequency	Receive frequency	Code
Brown	26.995MHz	26.540MHz	HX30H
Red	27.045MHz	26.590MHz	HX31J
Orange	27.095MHz	26.640MHz	HX32K
Yellow	27.145MHz	26.690MHz	HX33L
Green	27.195MHz	26.740MHz	HX34M
Blue	27.245MHz	26.790MHz	HX35Q

455kHz IF and 50kHz channel spacing.

Table 1. Radio control matched crystal pairs.

Notes on Assembly

A close inspection of all components, assemblies and solder joints is worthwhile before applying power to the project. Ensure all components are fitted as closely to the PCB as possible and all leads are correctly soldered. Check for short circuits across the tracks and clean off any flux that may have accumulated. Many projects fail due to poor assembly detail and bad soldering, so be fastidious at this stage if problems are to be avoided!

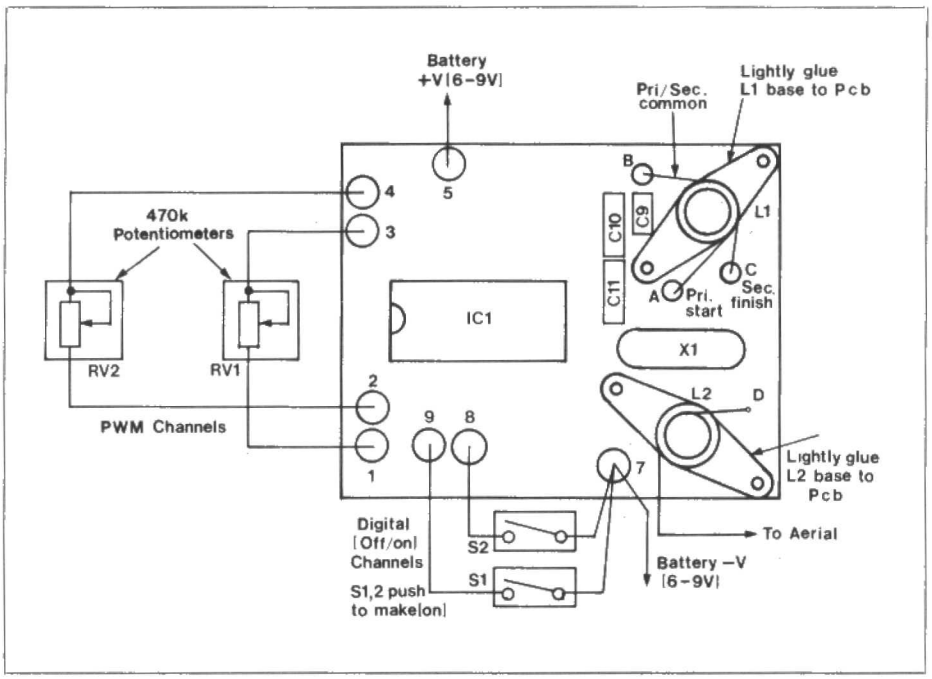


Figure 6. Wiring to Transmitter PCB

Wavemeter

Unfortunately, accurate adjustment of simple transmitters such as this does require test equipment other than a multimeter. A dedicated wavemeter, or grid dip meter that can be used as a wavemeter, is required for peaking L1 and L2. These items can be costly if not readily available so a simple circuit is given in Figure 7. If intending to build this circuit, it should be pointed out that no PCB is available and construction is a matter of choice. Figure 7B shows the prototype layout which was built on 0.1in. matrix Verostrip board. All components should be kept in close proximity with each other and the aerial soldered upright at its base. The coil is close wound on a 7mm former using 24swg enamelled wire (similar to L2, but without a dust core fitted). Make a small loop on top of the 18swg aerial wire and solder its base to the junction of L1, C1 and the diode. The circuit resonates at 27MHz and the meter indicates when a signal is being transmitted, but is not calibrated for field strength, and can only be used as a guide to maximum efficiency.

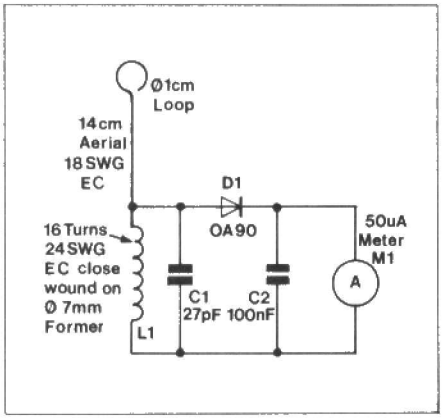


Figure 7A. Circuit diagram of a simple Wavemeter

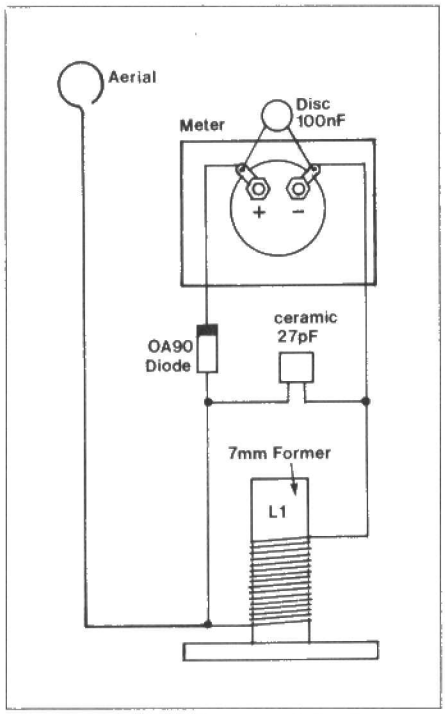
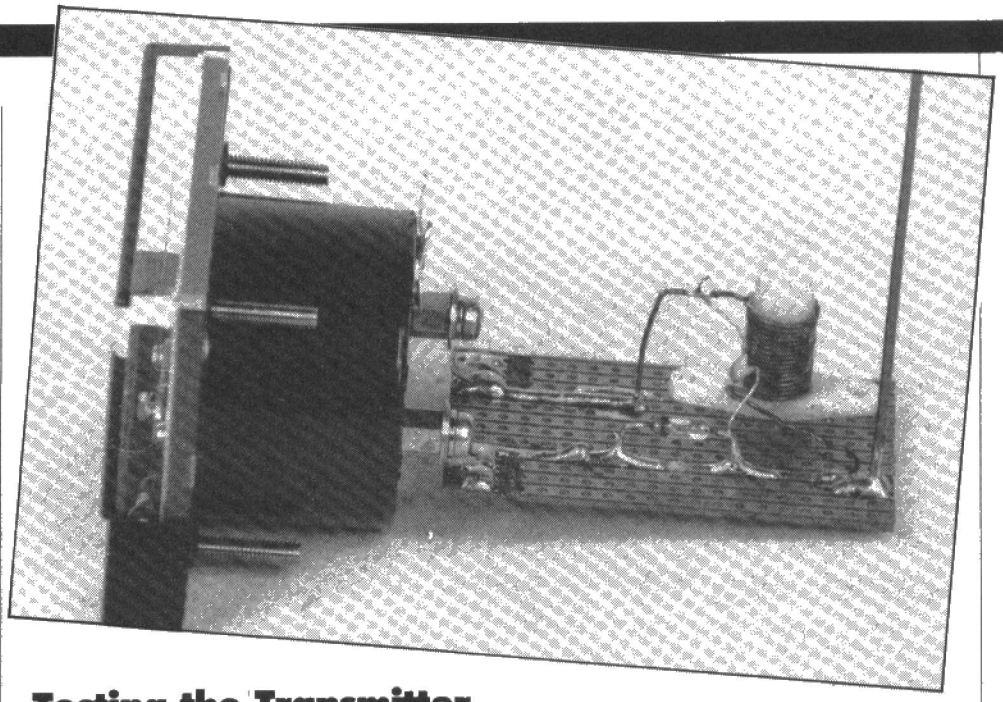


Figure 7B. Wiring diagram of simple Wavemeter



Testing the Transmitter

Connect RV1 between pins 1 and 3, and RV2 between pins 2 and 4 on the transmitter PCB (Figure 6). Connect the pot wiper to one of the resistance ends as shown in each case so that when turned its value is varied from 0Ω to 470kΩ. S1 and S2, if used,are wired between 0V (pin 7) and pin 8 or 9 as shown. These switches should be push-to-make and either latching or momentary action to suit requirements. Table 2 gives the result of S1/2 operation and approximate values for RV1/2. Current consumption of the transmitter is 10-15mA at 9V so a PP3 could be used for short periods. For preference use 6 AA size ni-cads (see Parts List) and a PP3 clip.

Connect the battery negative (black lead) to pin 7 and a multimeter between battery positive (red lead) and pin 5. The remaining wire end from coil L2 should be cut off allowing three inches extending from the coil. Place the pick-up from a wavemeter close to L2 or twist two turns of L2 round the aerial wire if using the Figure 7 circuit. Apply power and monitor the current on the multimeter set to read milliamps. Screw down the dust core of L1 in a clockwise direction and check the wavemeter reading which should gradually increase to a maximum field strength and minimum current which will be around 13mA. The Figure 7 meter should read close to half scale (10-30). Screw L2 core clockwise down into the former and the wavemeter reading should gradually increase then decrease. Finally readjust both L1 and L2 for maximum field strength and minimum current readings. As a guide, the prototype unit peaked at 12.98mA with 9V supply and a reading of 35 on the Figure 7 wavemeter. These figures will of course vary between different transmitters, but give an idea of what to expect.

If the current reading does not change when tuning and the wavemeter gives no indication, recheck RV1 and RV2 connections again as modulation stops if these connections are missing. No constant RF carrier is developed; it is only there when modulation is present. Check that crystal X1 is fitted correctly into its socket and L1 has been wired up correctly to the appropriate terminals. No

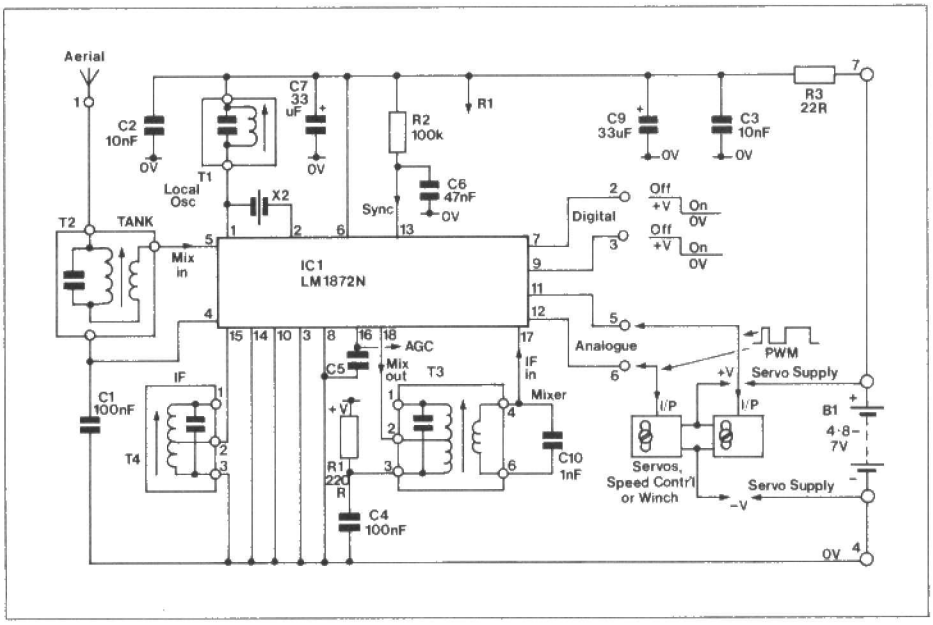


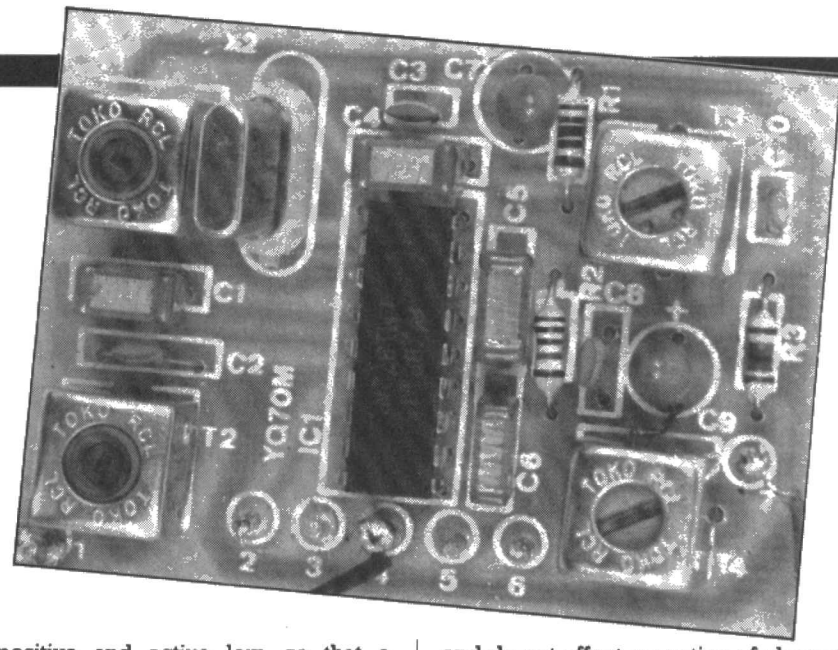
Figure 8. 27MHz Receiver circuit diagram

current or excessively high current readings could indicate anything from flat batteries to faulty meter leads or more serious PCB faults and further assistance must be sought. For constructors with oscilloscopes, connect a high impedance probe – preferably below 10pF capacitance to the aerial wire from L2 or wind a few turns of insulated wire around L2 connecting one end to 0V and the other to the probe. A waveform similar to Figure 3 (without the 1ms channel 3 and 4 pulses) should be displayed. If the scope bandwidth is low then you will only see the modulation present from IC1 pin 13.

Receiver

Figure 8, the circuit diagram, shows the receiver and external connections. Transmitted 27MHz signals are picked up by the aerial and coupled to the mixer via tank coil T2. This coil effectively keeps strong out-of-band signals like TV and FM broadcasts from cross-modulating with the required signal. A local oscillator consisting of T1 and X2 connects via IC1 pins 1 and 2 to the internal mixer section where the local oscillator and aerial signals are mixed at T3 primary (pin 18). The stepped down signal appears on IC1 pin 17 which is the intermediate frequency (IF) input. IF tuning is performed by T4. In the case of using 'blue band' crystals for example, the transmitter frequency will be 27.245MHz and the receiver local oscillator will run at 26.790MHz. When these two signals are present at the mixer, a difference signal is produced, in this case 27.245 – 26.790MHz = 455kHz. This is true for all crystal pairs which is why matching is important. The 455kHz signal or IF (since it is intermediate between the input RF frequency and the desired audio frequency) is recognised by a tuned bandpass filter T4, which only responds to frequencies in the range 455kHz ±3.2kHz (3dB). Sum and difference signals above 460kHz and below 450kHz are not amplified and become ineffective. This is basically how superheterodyne receivers, of which this is an example, function.

Pulsing the transmitted carrier on and off at set intervals will result in the IF producing a DC pulse related to this carrier modulation from an internal-detector within IC1. The detected signal is compared with an internal voltage reference so that whenever the peak IF exceeds 25mV, a comparator resets the internal digital envelope circuitry. This threshold level can vary according to the distance between the transmitter and receiver, which can result in high IF signal levels being developed. To minimise this, automatic gain control (AGC) is used to regulate the peak carrier level to 100mV by comparing it with an internal 100mV reference. An error signal is then produced which determines the gain of the IF amplifier at C5 pin 16. Digital outputs pins 2, 3, 5 and 6 are decoded and generated within IC1. Both pin 2 (channel 3) and pin 3 (channel 4) are normally high



or positive and active low, so that a negative pulse is produced whenever S1 or S2 are operated at the transmitter end. See Table 2. Pin 5 (channel 1), controlled by RV1 (pins 1 and 3) on the transmitter, develops a positive pulse output, whose width is 0.3ms to 2.0ms, every 20ms. Similarly, pin 6 (channel 2) is controlled by RV2 (pins 2 and 4) with the same duration positive pulse variation. Both channels are independent of one another

Transmit	Receive
RV1 or RV2 resistance	Pin 5 or 6 pulse width
0Ω	0.3ms
50kΩ	0.5ms
200kΩ	1.0ms
330kΩ	1.5ms
480kΩ	2.0ms
S1 open	Pin 2 high (+V)
S1 closed	Pin 2 low (0V)
S2 open	Pin 3 high (+V)
S2 closed	Pin 3 low (0V)

Frame rate = 20ms
Repetition frequency = 50Hz

Table 2. Transmit-to-receive characteristics

and do not affect operation of channels 3 and 4 (see Table 3).

Construction

Identify and fit the three resistors R1 to R3. Insert IC1 and solder all leads onto their pads. Cut off excess wires and fit C2, 3, 8 and 10 followed by the remaining capacitors. C7 and 9 are both polarised and their positive leads must align with the PCB legend. Fit crystal socket for X2 and Veropins 1 to 7. Again solder all components and remove excess wire ends. Correctly identify T1 to T4. Identification codes appearing in the Parts List are printed on the side of the metal cans. These components can only be fitted one way round, but some may have extra wide screen terminals connected to the metal can. If so it will be necessary to trim a small amount from the width with a pair of cutters. Carefully solder the 20 coil terminals and 8 screen terminals onto the PCB. As mentioned in the transmitter construction, clean and inspect the back face of the PCB carefully before proceeding.

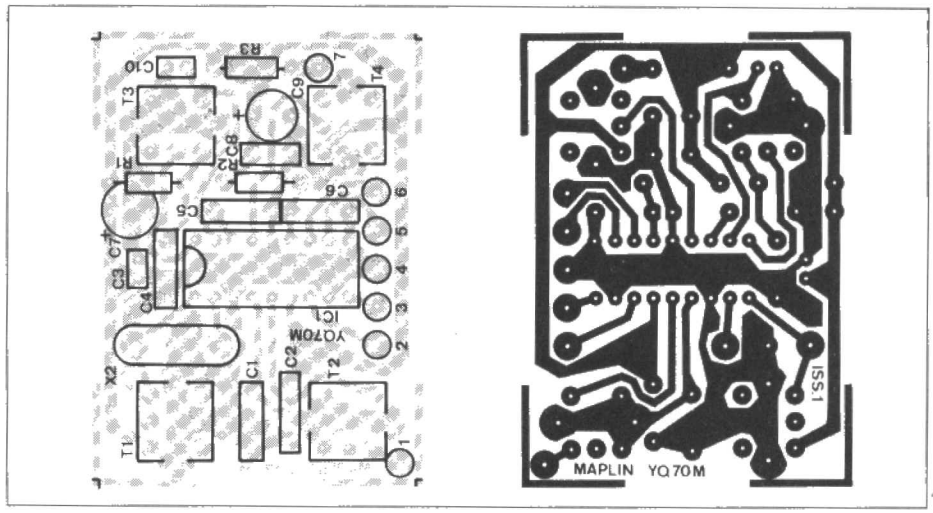


Figure 9. Track layout and overlay of Receiver PCB

Transmitter	Receiver	Description	Uses
RV1 – Pins 1 and 3	Pin 5	Channel 1 PWM O/P	Drives servo's, speed
RV2 – Pins 2 and 4	Pin 6	Channel 2 PWM O/P	controllers and yacht winches.
S1 – Pin 9 and 0V	Pin 2	Channel 3 Digital O/P	Active low operation, TTL com-
S2 – Pin 8 and 0V	Pin 3	Channel 4 Digital O/P	patible. Drives loads above 22kΩ.

Table 3. Pin connections and channel functions

Testing the Whole System

It is likely that you will wish to use the transmitter as a hand-held device and operate a model of some kind. Therefore a suitable case is required in which to mount the transmitter PCB, batteries, pot's and switches. Although it is a matter of taste, it is suggested that a small plastic box be used, large enough to accommodate the hardware and small enough to hold comfortably. A static system could best employ a metal box for better ground plane effect and hence possible increased range, especially with a larger transmitting aerial (see Aerials section). Whatever system is employed, re-tuning of L1 and L2 will have to be done after boxing up as tuning will be altered according to the proximity of additional components and your hand. Repeat the transmitter setting up procedure as before for optimum results. Leave the transmitter operating at a level of three to four feet above ground. Hold the working receiver with aerial attached and battery pack in one hand and move away from the transmitter. The earpiece buzz will most certainly stop after a while. Go back to the last working position and adjust T2 for maximum volume. Adjust T1 if necessary and continue moving away from the transmitter. Now T3 and T4 can be peaked for maximum. You will find that as the distance is increased, tuning becomes sharper and slug variations become smaller. In this way the optimum can be found for both transmitter and receiver.

Using the System

PWM output signals from either pins 5 or 6 (Rx PCB) will operate our servo and speed control projects for model boat and car applications. Because of the low power output from the transmitter, it is definitely not recommended that free-flying models be used as two or three pounds of balsa wood and aluminium hurtling out of the sky can be extremely dangerous! It is possible though for this project to be used with robotics models, with a microcomputer replacing S1, S2, RV1 and RV2 via a digital or D to A interface.

Testing the Receiver

Insert the lower frequency crystal, from the selected pair, into the holder. Connect the PP3 clip with positive (red) to pin 7 and negative (black) to pin 4. Solder an M3 tag onto pin 1 and bolt a telescopic aerial to the lug with a 12mm M3 bolt. Aerials of 1 to 2 feet in length should be satisfactory for short distance use. 20swg wire could be used, but a telescopic aerial is easier to manage. With the recommended trimming tool, turn T1 and T2 tuning slugs until they are level with the can top plate. Screw T1 clockwise into the former for 2 full turns and T2 for 3 full turns. Carefully turn T3 slug anticlockwise as far as it will go, and then turn it clockwise – down into the former – for 1¼ turns. Do the same to T4. These settings are approximate to begin with and readjustment will be necessary

PARTS LIST FOR 27MHz TRANSMITTER

RESISTORS: All 0.4W 1% Metal Film			
R1	56k	1	(M56K)
R2	100k	1	(M100K)
R3,5	47k	2	(M47K)
R4	220k	1	(M220K)
CAPACITORS			
C1	47µF 16V Tantalum	1	(WW76H)
C2	680pF Ceramic	1	(WX66W)
C3,4,5	100nF Minidisc	3	(YR75S)
C6	4n7F Ceramic	1	(WX76H)
C7	68pF Ceramic	1	(WX54J)
C8	10nF Polycarbonate	1	(WW29G)
C9	100pF Ceramic	1	(WX56L)
C10,11	22pF Mica	2	(WX05F)
SEMICONDUCTORS			
IC1	LM1871	1	(YY71N)
MISCELLANEOUS			
	Former 351	2	(LB17T)
	Dust Core Type 6	2	(LB42V)
	Printed Circuit Board	1	(YQ69A)
	Crystal Socket 25u	1	(HX60Q)
	E.C. Wire 30swg	1 roll	(BL40T)
	E.C. Wire 24swg	1 roll	(BL28F)
	Veropin 2141	1 pkt	(FL21X)
OPTIONAL			
X1	MCR Crystal (see Table 1)	1	(HX30H - HX35Q)
	Aerial 8-section	1	(RK48C)
	Aerial 6-section	1	(RK49D)
	PP3 Clip	1	(HF28F)
	Battery Holder 9V	1	(HQ01B)
	Battery AA Ni-Cad	6	(YG00A)
	Trimming Tool TT8	1	(BR50E)
RV1,2	Pot Lin 470k	2	(FW07H)
S1,2	Push Switch	2	(FH59P)

A kit of above parts (excluding optional items) is available.
Order As LK55K (27MHz Tx Kit) Price £9.95

PARTS LIST FOR 27MHz RECEIVER

RESISTORS: All 0.4W 1% Metal Film			
R1	220Ω	1	(M220R)
R2	100k	1	(M100K)
R3	22Ω	1	(M22R)
CAPACITORS			
C1,4,5	100nF Polycarbonate	3	(WW41U)
C2,3,8	10nF Ceramic	3	(WX77J)
C6	47nF Polycarbonate	1	(WW37S)
C7,9	33µF 10V Tantalum	2	(WW74R)
C10	1nF Ceramic	1	(WX68Y)
SEMICONDUCTORS			
IC1	LM1872	1	(YY72P)
MISCELLANEOUS			
T1,2	Toko CSK3464	2	(YG31J)
T3	Toko YRCS12374	1	(YG30H)
T4	Toko YMCS17104	1	(YG32K)
	Printed Circuit Board	1	(YQ70M)
	Crystal Socket 25u	1	(HX60Q)
	Veropin 2141	1 pkt	(FL21X)
OPTIONAL			
X2	MCR Crystal (see Table 1)	1	(HX30H – HX35Q)
	Aerial 8-section	1	(RK48C)
	Aerial 6-section	1	(RK49D)
	PP3 Clip	1	(HF28F)
	Battery Holder 6V	1	(HF29G)
	Battery AA Ni-Cad	4	(YG00A)
	Trimming Tool TT5	1	(BR50E)
	Crystal Earpiece	1	(LB25C)

A kit of above parts (except Optional items) is available.
Order As LK56L (27MHz Rx Kit) £10.95

later on. The coils perform the following fuctions:

T1 Local oscillator coil
T2 Aerial tank coil
T3 Mixer coil
T4 IF coil

As with the transmitter, expensive test equipment is needed for accurate alignment of the receiver stages, though not really necessary. A small crystal earpiece can be used to monitor one of the PWM channels, where a low-pitched 50Hz buzz can be heard. Remove the 3.5mm jack plug from the earpiece lead and solder one lead to 0V (pin 4) and the other to pin 5. Connect a multimeter set to read milliamps between pin 7 and the battery positive lead and apply power. Current reading should be about 13mA. Place the transmitter 2 to 3 feet away from the receiver and with no transmitting

aerial fitted, switch that on as well. Ensure that RF energy is being developed with your wavemeter and listen to the earpiece. If no buzz is heard, adjust T4 so that the slug screw slot faces along a line with pin 6 and pin 7 on the PCB. Turn T3 slug to the same position. Slight adjustment of both may be necessary to find the correct operating areas. When this is done, remove the meter and reconnect battery positive to pin 7.

PARTS LIST FOR WAVE METER

CAPACITORS				**MISCELLANEOUS**			
C1	27pF Ceramic	1	(WX49D)	M1	Hi-Z 50μA Meter	1	(FM98C)
C2	100nF Minidisc	1	(YR75S)		Former 351	1	(LB17T)
					E.C. Wire 24swg	1 roll	(BL28F)
SEMICONDUCTORS					E.C. Wire 18swg	1 roll	(BL25C)
D1	OA90	1	(QH71N)				

CORRIGENDA

Vol. 2 No. 5

Modem. Some confusion exists over which is the transmit and which is the receive LED on the Modem. Transmit is data out from the computer or interface. This is monitored by the LED marked D11. This LED will be on when the computer is powered up and will flicker when the computer is transmitting. Incoming data from line is monitored by the LED marked D10. This LED will light when the Modem is receiving a low tone from the distant Modem and will flicker when data is received.

Vol. 2 No. 8

Spectrum RS232 Interface. New issue 3 boards are now available which incorporate the corrections shown is Vol. 3, No. 11. However, two circles depicting track pins have been omitted from the screen overlay of the PCB. Both pins lie in the gap between IC6 and IC7 and one should be inserted adjacent to pin 23 of IC6 and the other is adjacent to pin 12 of IC7. Also note that resistor R11 must be soldered on both sides of the board.

Vol. 3 No. 9

Infra-red Movement Detector. Please note that the relay (RLA) has a break action when the Detector is triggered and is normally closed. Also moving RV1 clockwise decreases sensitivity and moving it anti-clockwise increases sensitivity. When mounting IDR1 it is best to bend it over to touch on the case of IC1 as this will ensure correct alignment with the reflector.

Vol. 3 No. 11

Mk II Noise Reduction Unit. Note that in figure 2, C5 should show the + side going to IC3a Pin 3.

Cautious Ni-Cad Charger. Note that in figure 2, IC5 should be shown as an AND gate not a NAND gate.

AMENDMENTS TO 1985 CATALOGUE

ROOM THERMOSTAT YB20W (Page 140). This item has been changed for a replacement type, but the photograph still shows the old type. Description is correct.

BLACK ANODISED KNOBS, HB39N & HB40T (Page 179). The photographs in the catalogue of these knobs have been incorrect for some time, but have managed to slip through the net yet again! The text is correct however.

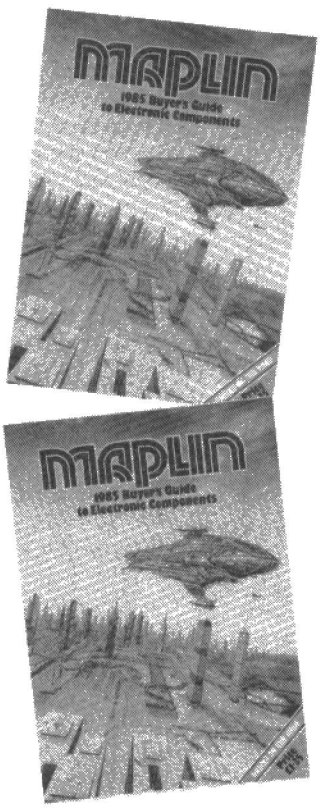
GRAPHIC EQUALISERS AF60Q, AF27E & AF59P (Page 189). The slider controls fitted to these do have a multi-position click effect, but not a specific centre click-stop action as stated in the descriptions in the catalogue.

GUITAR STRINGS LB60Q (page 191). The photograph shown should not include the packet of nylon strings, LB60Q is sold as a set of steel strings only.

RECTANGULAR METERS RW98G - RX53H (Page 208). The photograph shown of a Rectangular Meter is incorrect. These meters actually look like the Large Meter on opposite page, with a black coloured bottom portion of the face.

ETCH RESIST PEN HX02C (page 214). This pen has been changed for an improved, easier to use type. The text is correct but the photograph is of the old pen, which little resembles the new type.

FM RECIEVER MODULES' INTERCONNECTION DIAGRAM (Page 234). The VHF tuner head shown in the diagram has been superceded by the replacement type EF5803 (LW44X), the construction and connection of which are different. Modification diagrams are included with each latest type tuner head EF5803.



2N3819 QR36P (Page 297). This JuGFET device will henceforth be in a T092d case style, and not a T0106f package as before.

HEX NON-INVERTING 3-STATE BUFFERS YH11M & UB78K (Page 307). The captions for the internal circuit and pin-out diagrams are transposed with the the 7407 & 7417 devices which are actually the 14 pin package. The 74LS365 and 74HC365 devices are in the 16 pin package.

OCTAL NON-INVERTING 3-STATE BUFFER QQ56L, UB65V, UB66W (Page 308). In the case of the 74LS244, 74HC244 and 74HCT244 devices, the output-enable control input pins 1G and 2G are both active low, i.e. both internal control buffers should have inverting input symbols (like 74LS240 inverter version etc), and not as shown.

NE555 TIMER IC QH66W (Page 356). May be supplied as a MC1455PI, this is correct. The MC1455 IC is a direct equivalent device and a pin for pin replacement for the NE555, having the same electrical characteristics. Negligible differences may show up in rare cases however.

2716 EPROM QQ07H (Page 370). The 2716 does not have an access time of 250ns, but rather a minimum of 350ns. For most applications the 2716 can be taken as being compatible with CPU systems requiring an access time of ±450ns.

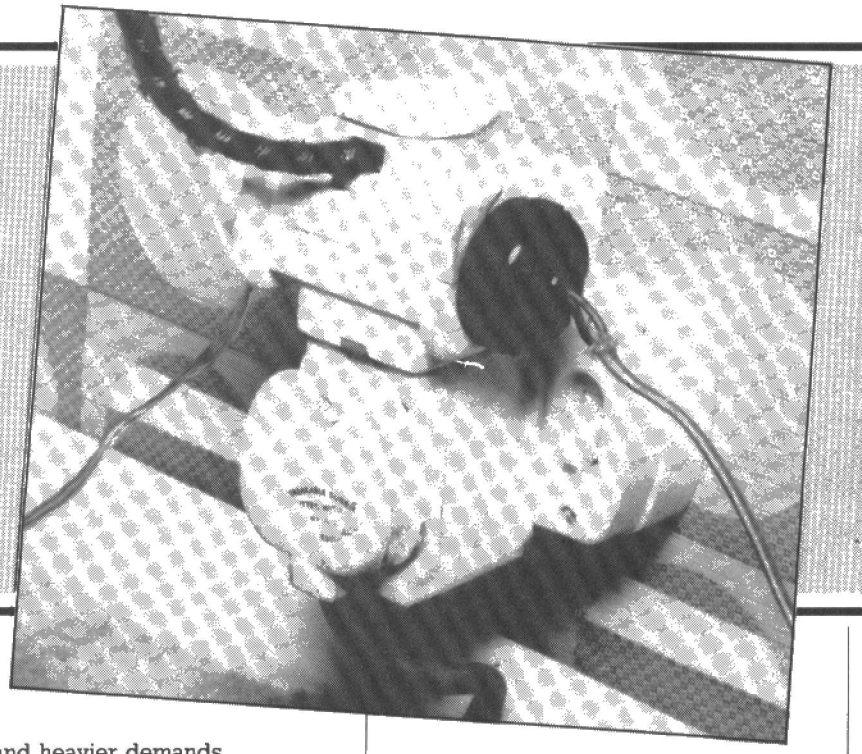
200W 15 INCH BIG CAT XG53H (Page 391) The specifications table should read 200W continuous rms, and not 100W rms as shown.

LOW COST FREQUENCY COUNTER YK38R (Page 410). This portable, battery powered digital frequency meter has changed slightly. Specifications are: Input Impedance, 1MΩ/20pF; Bandwidth, 10Hz to 50MHz; Power Supply, 6 x AA batteries or 9V DC @ 100mA; Battery Low Indicator, flashing unit sign; Battery Life, 4 hours; Dimensions, 111 x 36 x 125mm; Weight, 500gms. Supplied with BNC terminated coaxial test lead, instruction manual and batteries.

15W Line Transformer YX66W (Page 435). This item has been erroneously omitted from the catalogue, and is still available. Current price £3.36.

NOTED IN No. 11 Vol 3 MAGAZINE

Taken for Granted



by Mike VandenBurg, Marketing Manager, MK Electric Limited.

In the September-November 1983 issue of Electronics, the Maplin Magazine we took a comprehensive look at rewiring your house. In this issue we consider the important – but much neglected – matter of electrical safety.

Electricity plays an important role in our lives. It is obvious how much we all depend on electricity when going about our respective jobs in the office, factory, workshop or on site. And electricity is probably the greatest home help we can have.

Yet, most of us take the benefits of electricity for granted, perhaps not surprisingly when you consider how the home has become increasingly geared to maximum convenience. Just take a look round and see what a demanding user of electricity a home can be.

It seems nobody need get their hands dirty in the kitchen with blenders, mixers, yoghurt makers, slow cookers, fast cookers and so on. In the living room there's video and hi-fi equipment. And in the garden or shed there's a variety of electrically powered tools to make life easier. All of which means that the mains supply in your home is being subjected to heavier and heavier demands.

Electricity is the silent ever present servant. Unlike gas and water obvious to the senses of sound, touch or smell, electricity gives little indication when something is wrong. There are many instances where damage can occur to either property or the individual without prior warning. Unless something goes wrong it is rare for the householder to consider the need for an examination to be made of his electrical circuitry.

For the older property the electrical installation is most important. If the property hasn't been rewired in recent years using modern materials and accessories there is a very real risk of electric shocks, fire and damage.

Alarming

When you consider the alarming statistics concerning electrical accidents in the home then surely there is a need for more careful thought to this important subject.

We often say that something is 'as safe as houses' but when you realise according to RoSPA (The Royal Society for the Prevention of Accidents) nearly 40 per cent of all accidents in the UK take place in the home, just how true is this phrase? How safe are our homes?

Statistics also show that every week on average in this country someone is killed by electricity and that nearly 10,000 fires in residential dwellings are caused by electrical equipment. That's nearly 30 a day.

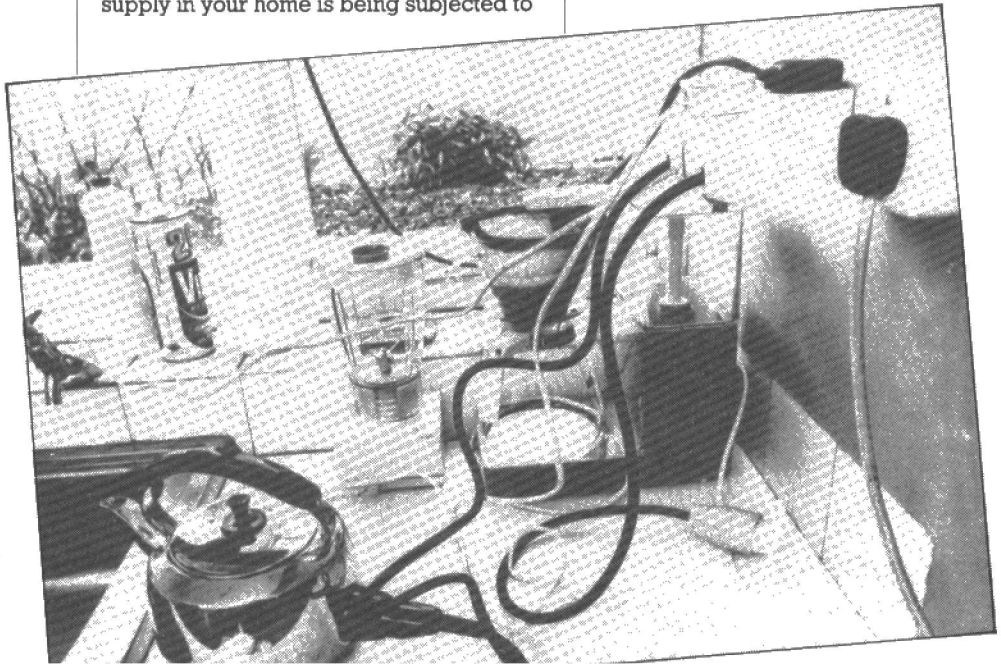
Growing Awareness

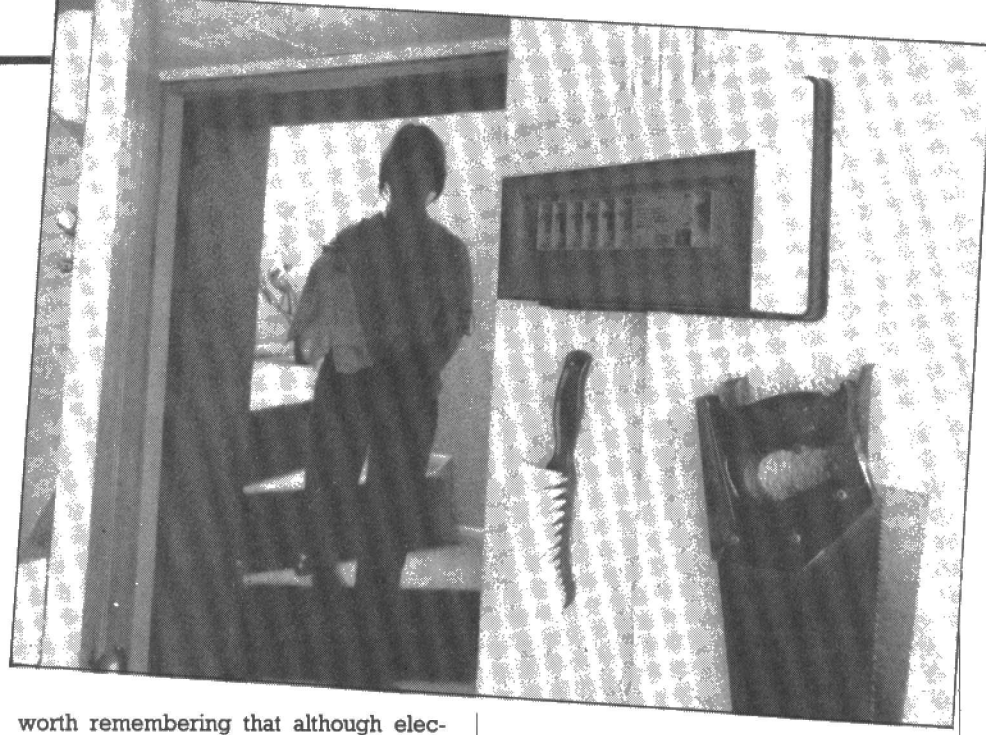
Perhaps changes in regulations in recent years indicate the growing awareness of the importance of electricity, and electrical safety. There are clearly defined attempts to reduce the risks associated with the use of electricity and bad electrical practice. On the surface electrical products themselves might not seem to have undergone any demonstrable change. Indeed if a lay observer were asked to compare the electrical accessories in a new house built at the beginning of the sixties with one built today, he may be hard put to spot too many differences.

Absorbed

The Ring Main for example has been well absorbed into practice following the consolidation into the 13th Edition of the IEE Wiring Regulations introduced in 1955. Its major provision for less cable, conduit and labour to make up the actual circuit with the facility to connect extra socket outlets without the need for additional wiring made a significant impact on a period of hectic rebuilding and redevelopment.

The 13th Edition was replaced in 1966 by the 14th with the main requirement that each socket outlet should be directly earthed to its earth terminal via the earth wire of a composite cable. This Edition carried many other amendments up to 1976, when discussion commenced on the 15th Edition, which emphasized the need for MCB's (miniature circuit breakers) and RCB's (residual current operated circuit breakers), which in indi-





vidual or consumer unit configurations are becoming increasingly important.

Impetus

A major impetus for this development has been the Health and Safety at Work Act, 1974. It had a significant effect on the installation and maintenance of electrical accessories. It forced all relevant parties in the electrical, building and specifying industries towards much closer and more frequent consultation on matters of electrical safety.

As regulations, legislation and British Standard documents have influenced the 'workings' of electrical products in connection with electrical safety, so new design concepts and materials have produced changes to style and finish.

Innovations

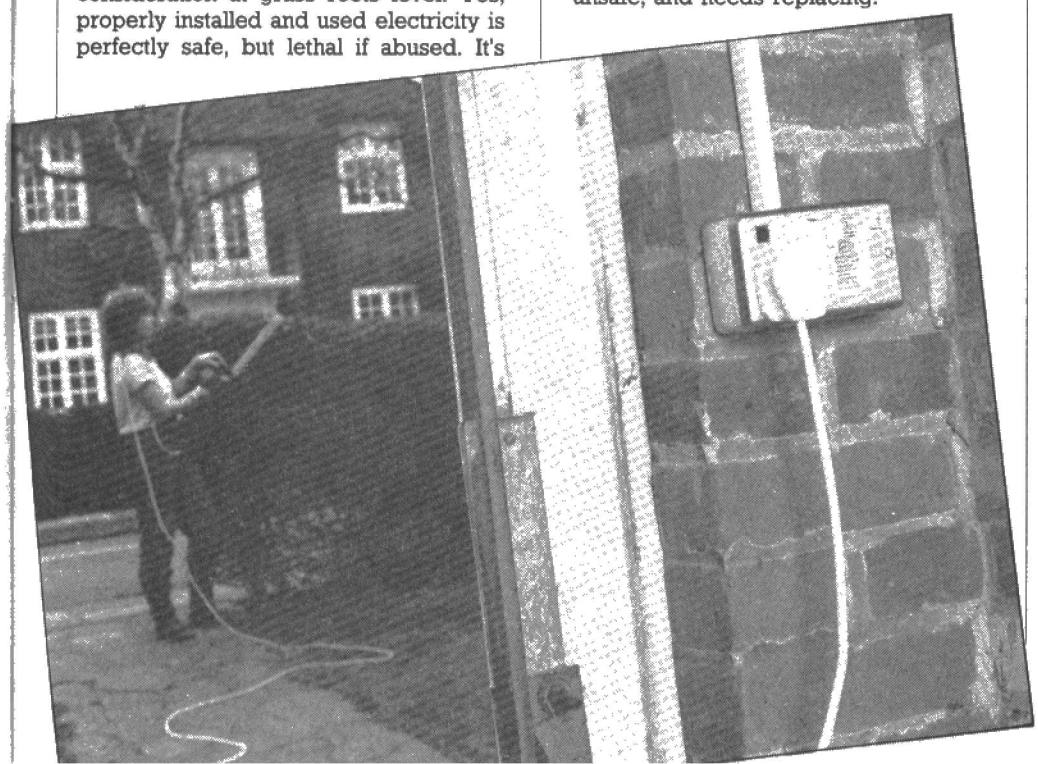
My company for example, as market leaders, in the early sixties introduced such technical and far reaching innovations as sliding shutter safety precautions on all socket outlets, captive screws and washers, equal length conductors and high quality finish. Then came our unique safety plug in 1971 – which became a by-word for technical design and safety. In addition our Logic range introduced in the mid-seventies acknowledged the trend toward product branding with a comprehensive range of matching accessories. With its clean, sharp lines and emphasis on rocker switches, Logic indicated the growing role architects, specifiers and consultants began to play as they sought the safest items to complement the ambience of properties under their direction.

Grass Roots

So as can be seen attempts have been made to avoid some of the dangerous pitfalls concerning electricity, but there is still a strong requirement for consideration at grass roots level. Yes, properly installed and used electricity is perfectly safe, but lethal if abused. It's worth remembering that although electricity is 'unseen' it does have a 'load value', and it is vital that the wiring installation will support that load which rises and falls many times in the course of the day. What can the householder do to minimise the risk of, say, an electrical fire or to ensure the most reliable personal protection? There are a number of steps to be taken.

Checked

Firstly have your wiring checked by experts. There are plenty of conscientious and reputable electrical contractors willing to advise and carry out electrical installations if required. Any house containing electrical circuitry 30 years old, and which has not since been rewired needs to be thoroughly checked by a qualified electrician. However good the original wiring and fixtures, no matter how expertly installed or carefully maintained, the material that was used over 30 years ago to insulate the wires from each other within the cables may have deteriorated so much that the wiring is now unsafe, and needs replacing.



If the wiring itself is fairly new and does not need replacing, take stock of all the electrical appliances you didn't have two or three years ago. Ask yourself if you shouldn't have a number of extra sockets installed.

Abuse

An inadequate number of socket outlets usually leads to the use of adaptors, and often the subsequent abuse of the electrical system. Just count up the number of electrical appliances in constant use in your home, and then add up the number of socket outlets. Ideally there should be one socket outlet for each major appliance with spares for certain appliances to make your life easier as well as safe.

Also the location of the power point is important, as trailing cables, such as when the appliance is situated too far from the socket outlet, can be a high-risk factor. It can cause, in the event of tripping over, personal injury, or the wire to be pulled out of the terminals in the plugs and increase the risk of electric shock or fire. Again the electrician can advise the most sensible approach.

Plugs

And plugs? Well a survey carried out by my company showed that 70 million potentially dangerous plugs were in use in British homes. Such common faults were incorrect wiring, ineffective cord grips, faulty terminal connections etc.

Plugs should be wired correctly using the correct colour codings and only plugs to British Standard with the safety mark should be used. Unfortunately there are many cheap, poor quality, imported plugs available from retail shops. These should never be used.

Distributed

Electricity is distributed in the home for uses such as power, light, cookers, central heating and so on, through a fuseboard. There are various types. Probably it incorporates devices known as rewirable fuses, where if the fuse blows it is necessary for the correct replacement

fusewire to be fitted. If this is not available some people actually use nails, paper clips, hair grips, even silver paper to bridge the gap between the two terminals and to restore the supply. This is highly dangerous and should never be attempted.

Advanced Systems

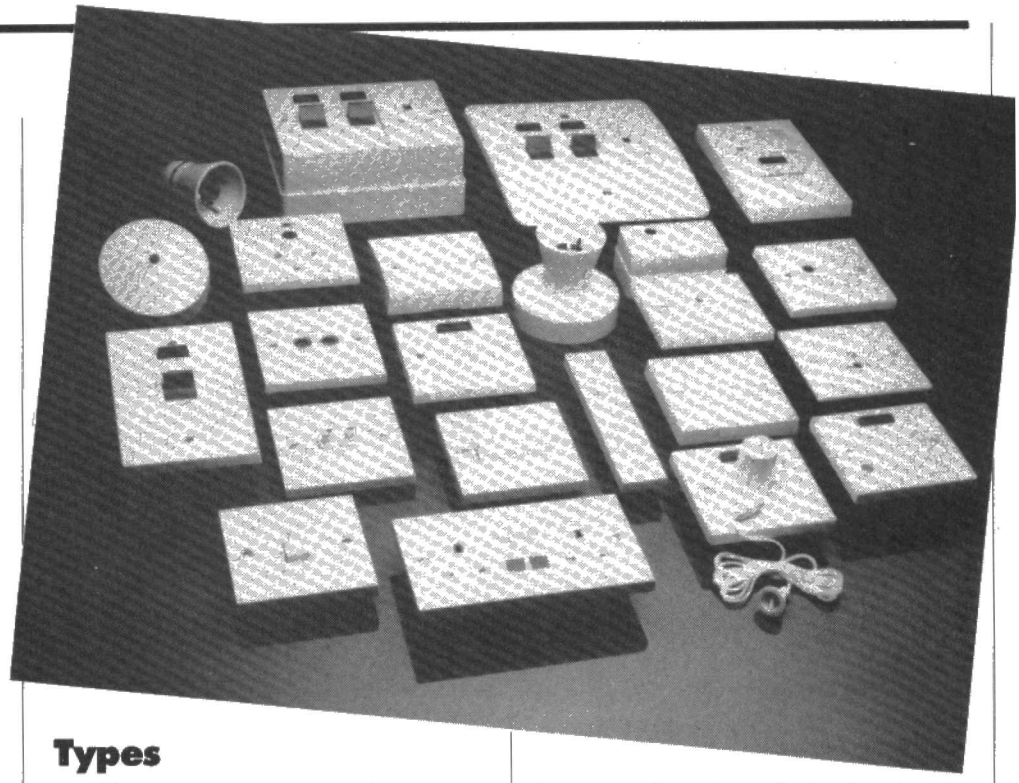
In the newer property, planning and selection of the most reliable electrical fittings is a much simpler task than for the older building. There are now many modern advanced systems for distributing electricity to where it's needed in the house. It behoves any householder to consider these developments. After all what price the safety of your family? The modern consumer unit is such a development and replaces the traditional 'mains box'.

A consumer unit contains a number of fuseways and a double pole isolating switch. Both from a safety and practical point of view consumer units have a number of advantages. And if you have an old distribution system it's worth bringing it into line with current wiring practice.

From the safety aspect old switch and fuse units and fuseboards themselves often have double pole fusing, which means that the live (phase) and neutral of each circuit have separate fuses. A situation could arise in which a fault on the circuit causes the neutral fuse to blow but leaves the one on the live side intact. The result is an ineffective safety device, as part of the circuit could still be live. So if you have double pole fusing it's important for safety reasons that it is replaced.

Consumer units have single pole fusing which means that the fuse is connected to the live side of the circuit only. When this blows as a result of a fault of an overload all power to the circuit is cut off: no part remains live.

However simply having a new consumer unit installed will not by itself renew the standards of an old wiring system. If the wiring is old it is potentially lethal. If you intend to upgrade your installation through a new consumer unit then it is vital that you still have the existing wiring checked by a competent electrical contractor.



Types

There are various types of consumer units available with six, eight, ten or twelve fuseways, some with rewirable fuses and cartridge fuses. Yet, the safest and most reliable are those which incorporate devices called residual current operated circuit breakers (RCB's) and miniature circuit breakers (MCB's).

My company's Sentry consumer unit incorporates these and is at the heart of the MK Shield of Safety Scheme, which literally offers the owners of 10,000 new homes the safest and most advanced electrical wiring system.

The RCB in the consumer unit monitors the electrical current in the home 24 hours a day, thus providing the individual with a high degree of protection against electrocution, and the property from the dangers of fires caused by electrical earth faults. The RCB switches off the current in a fraction of a second if a potentially dangerous current leakage occurs – quick enough to save a life.

It's worth noting that danger to life can occur when a very low level of current leaks to earth through an individual. For example between 1-3 milliamps an electric shock is felt. Between 6-10 milliamps the individual finds it hard to let go of the appliance. Above 25 milliamps and there is real danger of heart attack and paralysis. And it only takes one quarter of an amp leakage to earth to start a fire.

The MCB's switch off instantly in the event of a short circuit or overload. Unless the fault is located the MCB will trip again and again – and there is no way that silver paper and nails can find their way into these. Only when the fault is cleared can it be reset. An MCB is therefore a much safer device than a fuse.

Outdoors

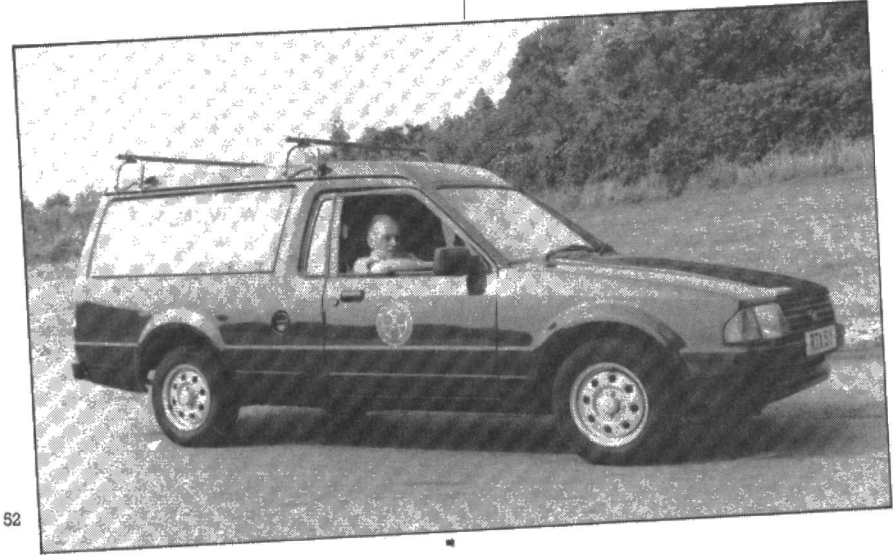
Where electrical tools are used outdoors – for jobs in the workshop, garden or garage a socket outlet incorporating an RCB should seriously be considered. Again the RCB will act should an earth leakage occur as a result of an appliance fault, frayed or accidentally cut cable, bad wiring etc, thus protecting against electric shock.

There are many types, but those like my company's 13 amp Sentrysocket switch socket outlets are probably the most reliable and safest. Unlike the RCB plug types available which can be dropped, become cracked and their efficiency impaired this type can be safely installed into the space vacated by a twin gang socket.

Awareness

So we hope you now appreciate the importance of safety when tackling electricity. If you are in any doubt, do not assume things will correct themselves, but consult a registered electrical contractor, preferably a member of the Electrical Contractors Association or NICEIC (National Inspection Council Electrical Installation Contracting) approved. He will advise you not only on the work that needs to be done, but on which electrical accessories to install.

But perhaps it is the need for a keener awareness by us all not to take electricity for granted and to ensure that it is electrical safety first before all other considerations.



MAGNIFICENT

Resistance Meter

by Robert Penfold

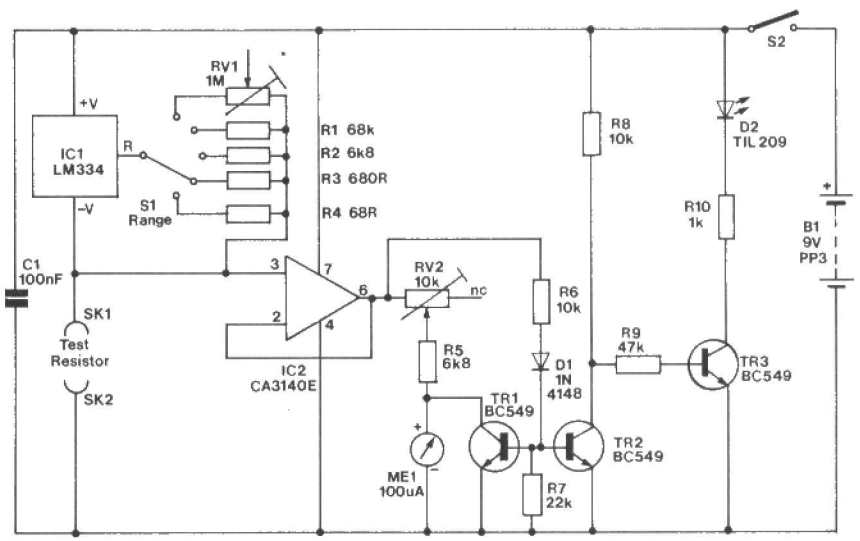
Although practically any multimeter is capable of resistance measurements, apart from digital instruments the number of resistance ranges provided is often rather limited, and the reverse reading non-linear scale is not very convenient in use. This resistance meter, despite being an analogue type, has a forward reading linear scale, and five ranges having full scale values of 1k, 10k, 100k, 1M, and 10M. It can therefore be used to test virtually any resistor that will be encountered in the course of normal electronic project construction and servicing.

The unit uses the same operating principle that is utilized by digital multimeters during resistance measurements. A constant current source is used to provide a certain current to the resistor under test. The voltage developed across a resistor, given a fixed current, is proportional to the value of the resistor. Therefore, if a voltmeter circuit is used to measure the potential developed across the resistor, the meter can in fact be calibrated directly in terms of resistance. For example, consider a test current of 1 milliamp and a voltmeter with a full scale sensitivity of 1 volt. A value of 1 kilohm would give a potential of 1 volt (1000 ohms x 0.001 amps = 0.1 volts) and only 10% of full scale deflection on the meter. In other words the meter reading is proportional to the test resistance, and a forward reading linear scale is obtained.

In the practical circuit IC1 provides the test current, and the LM334 is specifically designed as a current regulator. S1 provides five switched currents of nominally 0.1μA, 1μA, 10μA, 100μA, and 10mA, giving the unit its five measuring ranges. The lowest current is actually outside the recommended operating range of the LM334, but provided this current is trimmed to the right level by means of RV1, accurate results are obtained on this range (the 10M range). The output currents on the other four ranges are controlled by precision (1%) resistors which ensure that good accuracy is obtained on these ranges. The voltmeter circuit must take no significant current from the test resistor if usable results are to be obtained, and IC2 provides the necessary buffering between the test resistor and the meter circuit. IC2 has a MOS input stage which consumes no significant input current. RV2 controls the sensitivity of the meter circuit and is used to calibrate the unit.

With no test resistor connected across the input the meter would be driven well beyond its full scale value. This problem is overcome by the inclusion of R6, D1, TR1, and R7. With the meter driven within its full scale value the output voltage of IC2 is too low to switch on TR1, and the unit functions normally. However, with an output voltage that is more than marginally above the full scale potential of the meter circuit TR1 is switched hard into conduction, and it limits the deflection of the meter to a very low level. TR2 and TR3 activate LED indicator D2 when a valid reading is present on ME1.

The unit is calibrated using (say) a 100k 1% resistor, with the unit switched to the 0 to 100k range. RV2 is then adjusted for precisely full scale deflection of the meter. Then the unit is switched to the 10M range, a 10M 1% resistor is connected across SK1 and SK2, and RV1 is adjusted for precisely full scale deflection of ME1.

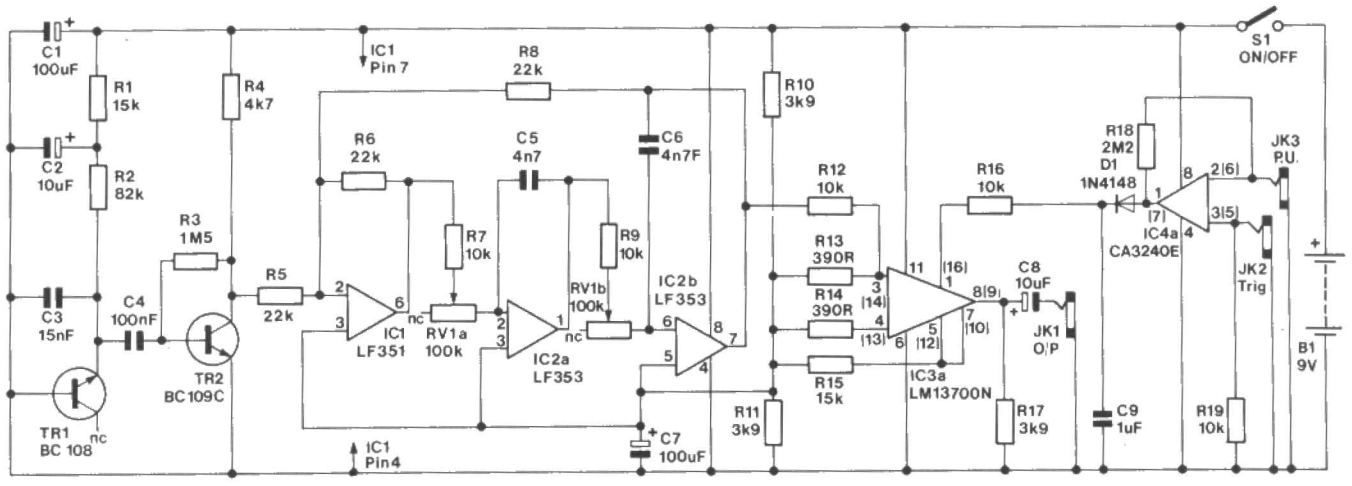


Woodblock Synthesiser

Woodblock synthesisers are perhaps not the best known type of percussion synthesiser, but they are capable of producing useful effects and are something electronic music enthusiasts should not overlook. This woodblock synthesiser can be triggered either by hitting the pick-up or by means of a +5 volt trigger pulse of a few milliseconds in duration. The pitch is adjustable over a wide frequency range.

A woodblock sound requires a fairly complex waveform since it consists of not just a fundamental signal plus harmonics, but a fundamental signal plus other frequencies close to this fundamental one. A suitable waveform cannot be produced using an oscillator, and the most simple method of generating a satisfactory signal is to use a noise source plus a very narrow bandwidth bandpass filter.

In this circuit the basic noise signal is generated by the reverse biased base/emitter junction of TR1. This breaks down at about 6 volts in zener diode fashion, and like a zener diode generates noise spikes. The noise output is greater than that from a zener diode though, but the high level of amplification provided by common emitter amplifier TR2 is still needed in order to give a strong output. TR1 can be virtually any npn silicon transistor, and in practice it is probably best to try a few devices from the spares box to find one that gives a really good noise output. C3 provides some initial



lowpass filtering that prevents the final output from having an excessive high frequency content.

The output from TR2 is fed to what is really a state variable filter (and which is based on IC1 and IC2). However, in this case it is only the lowpass output of the filter that is utilised – the highpass and bandpass outputs just being ignored. The filter is used at a high Q value so that a narrow and pronounced peak is produced in the frequency response just below the cut-off frequency, and the type of filtering obtained is actually a cross between bandpass and lowpass filtering. This gives an excellent output signal for this application, and the pitch of the output can be varied from about 200Hz to 20kHz by means of RV1.

Envelope shaping is, of course, essential if a usable effect is to be obtained. In this circuit IC3a operates as the voltage controlled amplifier, and this is a straightforward circuit using an operational transconductance amplifier. IC4 and its associated components generate a simple attack – decay control voltage from the input trigger pulse or the pulses from the pick-up. The latter can be a ceramic resonator or a crystal microphone insert.

One section of IC3 is left unused, and the pin numbers for the unused section are shown in brackets on the circuit diagram. In practice the unit would be most useful if two or more synthesisers are constructed, and the second section of IC3 does not have to be wasted. The noise source can be used for several synthesisers, but the filter, envelope generator, and VCA circuits would need to be duplicated for each synthesiser. If several synthesisers are built and they are to be triggered by pick-ups it is essential to have these reasonably well (physically) isolated from one another to prevent unwanted multiple triggering from occurring.

RESISTANCE METER PARTS LIST

RESISTORS – All 0.4W 1% Metal Film			
R1	68k	1	(M68K)
R2,5	6k8	2	(M6K8)
R3	680Ω	1	(M680R)
R4	68Ω	1	(M68R)
R6,8	10k	2	(M10K)
R7	22k	1	(M22K)
R9	47k	1	(M47K)
R10	1k	1	(M1K)
RV1	1M Hor S-Min Preset	1	(WR64U)
RV2	10k Hor S-Min Preset	1	(WR58N)
CAPACITORS			
C1	100nF Ceramic	1	(BX03D)
SEMICONDUCTORS			
IC1	LM334	1	(WQ32K)
IC2	CA3140E	1	(QH29G)
TR1,2,3	BC549	3	(QQ15R)
D1	1N4148	1	(QL80B)
D2	Red LED	1	(WL32K)
MISCELLANEOUS			
SK1,2	1mm Socket	2	(WL59P)
S1	Rotary Switch 2-pole 6-way	1	(FF74R)
S2	SPST Ultramin Toggle	1	(FH97F)
ME1	100μA Panel Meter	1	(RW92A)
B1	Battery 9V PP3	1	(FK62S)
	Battery Connector	1	(HF28F)
	DIL Socket 8-pin	1	(BL17T)

WOODBLOCK SYNTHESISER PARTS LIST

RESISTORS – All 0.4W 1% Metal Film unless specified			
R1,15	15k	2	(M15K)
R2	82k	1	(M82K)
R3	1M5 ⅓W 5% Carbon	1	(B1M5)
R4	4k7	1	(M4K7)
R5,6,8	22k	3	(M22K)
R7,9,12,16,19	10k	5	(M10K)
R10,11,17	3k9	3	(M3K9)
R13,14	390R	2	(M390R)
R18	2M2 ⅓W 5% Carbon	1	(B2M2)
RV1	Dual Pot Lin 100k	1	(FW88V)
CAPACITORS			
C1,7	100μF 10V Axial Electrolytic	2	(FB48C)
C2,8	10μF 25V Axial Electrolytic	2	(FB22Y)
C3	15nF Polyester	1	(BX71N)
C4	100nF Polyester	1	(BX76H)
C5,6	4n7F Carbonate	2	(WW26D)
C9	1μF Carbonate	1	(WW53H)
SEMICONDUCTORS			
IC1	LF351	1	(WQ30H)
IC2	LF353	1	(WQ31J)
IC3	LM13700N	1	(YH64U)
IC4	CA3240E	1	(WQ21X)
TR1	BC108C	1	(QB32K)
TR2	BC109C	1	(QB33L)
D1	1N4148	1	(QL80B)
MISCELLANEOUS			
JK1,2,3	6.35mm Jack Socket	3	(HF91Y)
S1	SPST Ultramin Toggle	1	(FH97F)
B1	Battery 9V PP9 Size	1	(FM05F)
	Battery Connector	1	(HF27E)

Atari 8 Channel ADC

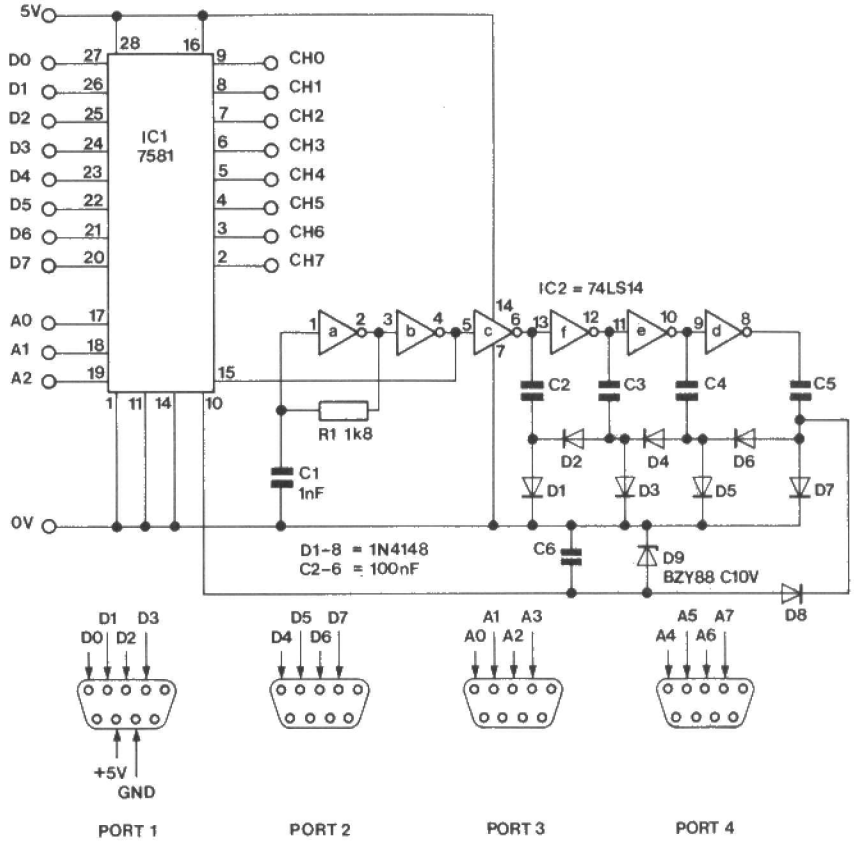
Although the Atari computers seem to be mainly thought of as games machines, they probably have more potential for user add-ons than most Atari users realise. The joystick ports of the Atari 400 and 800 computers provide what is effectively two 8 bit input/output ports with each line individually programmable to act as an input or an output. The 600XL and 800XL are rather more limited in that they only have two joystick ports, and therefore one 8 bit input/output.

The joystick ports have two analogue to digital converters per port, but these are resistance operated converters and not the more useful voltage sensitive type. However, it is quite easy to interface a high quality analogue to digital converter to the digital inputs of the joystick ports, and a suitable 8 channel design based on the CMOS 7581 device is shown here. Apart from the normal +5 volt supply a −10 volt reference source is required for this device. The 7581 also needs an external clock supplying a frequency of about 1 to 1.6MHz. In this case IC2a is used as a simple relaxation oscillator operating at typically just over 1MHz, and IC2b provides a buffered output for the clock input of the 7581 (IC1). The clock signal is applied to a series of four more buffers, and each of these drives a rectifier circuit that gives a negative output. The four rectified outputs are effectively connected in series, smoothed by C6, and then limited to −10 volts by zener diode D9. This gives the required reference voltage to pin 10 of IC1. This potential sets the full scale input sensitivity of each channel at 10 volts.

The 7581 has a quite complex internal circuit, but it is basically a successive approximation converter, 8 by 8 RAM, and eight input analogue multiplexer. The action of the device is to convert each channel in turn and store the result in the appropriate 8 bit RAM location. By reading one of the RAM locations the latest value for the corresponding channel is obtained (each channel is updated approximately every 500uS, or 2000 times per second). D0 to D7 carry the 8 bit output from the selected channel, while A0 to A3 are inputs which are used to select the required channel. A connection diagram for the four joystick ports is included here, and note that five lines are left unused and are therefore free to act as outputs if the converter is used in a control application. Connection to the joystick ports is via 9 way D sockets.

The converter can be read at address 54016 using the PEEK function (e.g. PRINT PEEK (54016) would print the returned value on screen). However, first the three address outputs must be set up as outputs and used to select the desired channel. The following commands achieve this:–

```
POKE 54019,56
POKE 54017,255
POKE 54019,60
POKE 54017,X
```



Here X is simply the number of the channel that you wish to read. The above routine sets A3 to A7 as outputs incidentally, and these can be controlled by POKEing the appropriate value to address 54017 (remembering to also set A0 to A2 to the right states when the converter is to be read).

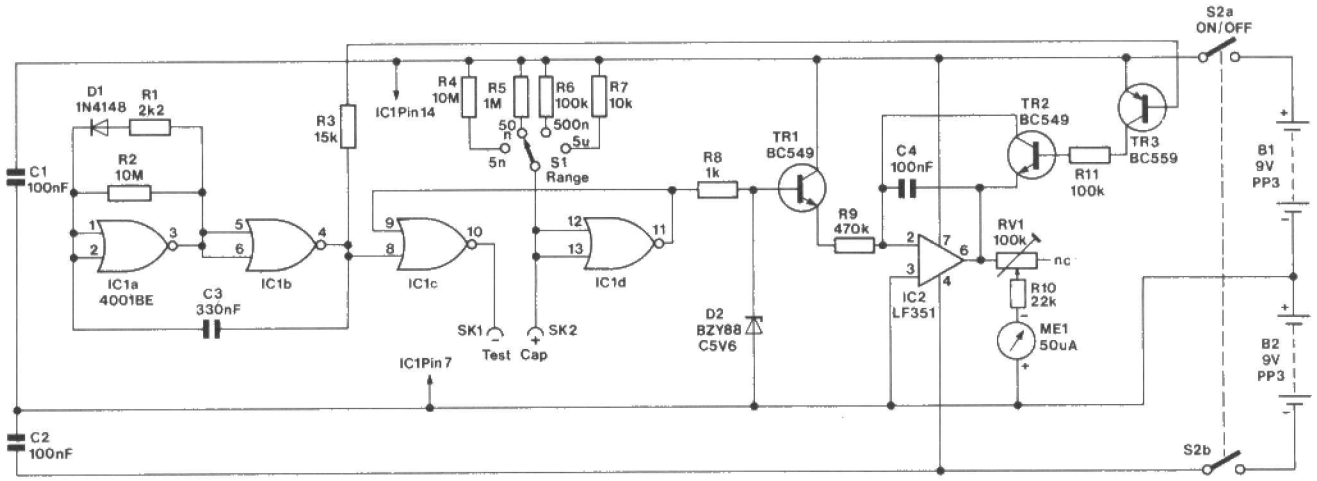
The unit could be used with a 600XL or an 800XL, but only as a single channel converter since joystick ports 2 and 3 are not fitted to these machines, and no means of selecting the desired channel is available. A0 to A2 would therefore be earthed, and only channel 0 would be used. Another problem if the unit is used with a 600XL or 800XL is that there would be no spare lines to act as outputs if the equipment is needed for a control application.

Capacitance Meter

This capacitance meter has four ranges with full scale values of 5nF, 50nF, 500nF and 5μF, enabling it to be used for checking most capacitors. It cannot be used to test high value electrolytic capacitors, but as these can be checked satisfactorily using an ordinary multimeter this is not a serious flaw. Although the unit has a quite simple circuit it is capable of excellent accuracy provided it is calibrated properly. No special equipment (apart from one close tolerance capacitor) is needed in order to calibrate the meter.

The circuit is based on a monostable multivibrator which is built around two CMOS 2 input NOR gates (IC1c and IC1d) and utilizes a standard configuration. The capacitor under test is the timing capacitor in the monostable, and the timing resistor is one of four switched components (R4 to R7) which gives the unit its four ranges. The monostable's output pulse duration is proportional to the value of the test capacitor, and some means of converting the pulse length into a corresponding meter reading is required. This is achieved by feeding the output pulse to the input of a Miller Integrator. The latter is a conventional operational amplifier type which is built around IC2. The basic action of the circuit is to give an output voltage that goes negative at a linear rate while the input pulse is present. In other words it gives the required pulse length to voltage conversion, and RV1 can be set up so that the unit provides direct readings in capacitance. R8 and D2 effectively stabilise the output pulse voltage of the monostable so that variations in supply voltage do not significantly affect the calibration of the unit. The output pulse length of the monostable does not seem to be supply dependent, and it is not necessary to use a stabilised supply for this section of the circuit.

IC1a and IC1b form a low frequency astable circuit which provides a brief negative output pulse about once per second. R1 and steering diode D1 are used to give the astable circuit the required non-symmetrical output waveform. The trailing edge of this signal is used to trigger the monostable and automatically take new readings at about one



second intervals. C4 must be discharged before a new reading is taken, and this is accomplished by TR2 and TR3 which are biased into conduction during each of the brief negative output pulses from the astable circuit.

In order to calibrate the unit a close tolerance capacitor having a value which is something approaching the full scale value of one of the ranges is required. For example, a 47nF capacitor has a value that is close to the maximum reading on the 50nF range, and could be used to calibrate the unit while it is switched to this range. It is simply a matter of connecting the calibration component to SK1 and SK2 and then carefully adjusting RV1 to obtain precisely the correct reading. Provided R4 to R7 are 1% tolerance resistors the unit will give good accuracy on all four ranges.

The unit can be used to check electrolytic capacitors provided they are connected with the polarity indicated on the circuit diagram, and they are of reasonable quality. Components having high leakage levels may not give a reading, but would obviously be of doubtful worth anyway. There should be no need to recalibrate the meter as its 0 to 50 scale is quite convenient for all four ranges.

ATARI 8-CHANNEL ADC PARTS LIST

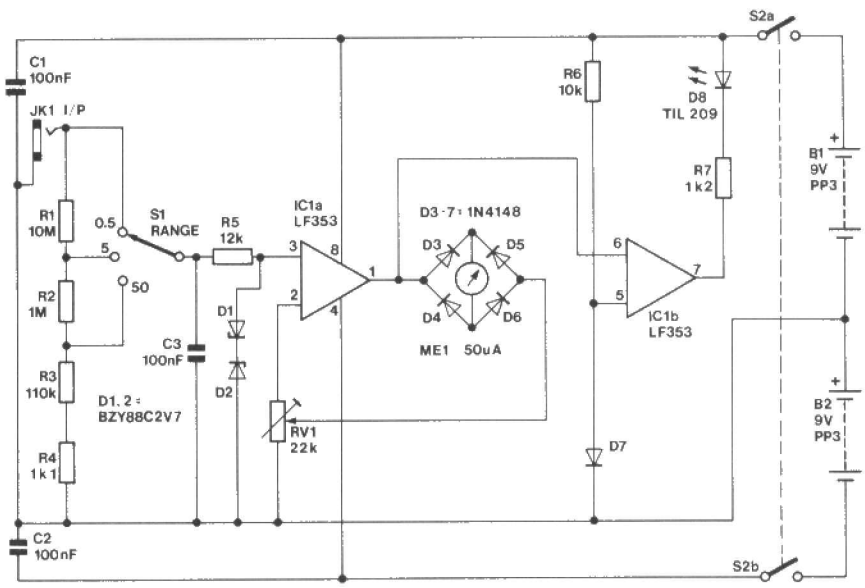
RESISTORS – All 0.4W 1% Metal Film			
R1	1k8	1	(M1K8)
CAPACITORS			
C1	1nF Carbonate	1	(WW22Y)
C2-6	100nF Polyester	5	(BX76H)
SEMICONDUCTORS			
IC1	7581	1	(QY56L)
IC2	74LS14	1	(YF12N)
D1-8	1N4148	8	(QL80B)
D9	BZY88C10V	1	(QH14Q)
MISCELLANEOUS			
	DIL Socket 28-pin	1	(BL21X)
	D Socket 9-way	3	(RK61R)

CAPACITANCE METER PARTS LIST

RESISTORS – All 0.4W 1% Metal Film							
R1	2k2	1	(M2K2)				
R2,4	10M	2	(M10M)	IC2	LF351	1	(WQ30H)
R3	15k	1	(M15K)	TR1,2	BC549	2	(QQ15R)
R5	1M	1	(M1M)	TR3	BC559	1	(QQ18U)
R6,11	100k	2	(M100K)	D1	1N4148	1	(QL80B)
R7	10k	1	(M10K)	D2	BZY88C5V6	1	(QH08J)
R8	1k	1	(M1K)				
R9	470k	1	(M470K)	MISCELLANEOUS			
R10	22k	1	(M22K)	S1	Rotary Sw 3-pole 4-way	1	(FH44X)
RV1	100k S-Min Hor Preset	1	(WR61R)	S2	DPST Rotary	1	(FH57M)
CAPACITORS				ME1	50μA Panel Meter	1	(RW91Y)
C1,2,4	100nF Polyester	3	(BX76H)	SK1	1mm Socket Black	1	(WL59P)
C3	330nF Polyester	1	(BX79L)	SK2	1mm Socket Red	1	(WL60Q)
SEMICONDUCTORS				B1,2	Battery 9V PP3	2	(FK62S)
IC1	4001BE	1	(QX01B)		Battery Connector	2	(HF28F)
					DIL Socket 14-pin	1	(BL18U)

High Z Voltmeter

DC voltage measurements made using an ordinary analogue multimeter can sometimes be misleadingly low. This problem occurs when checking low current circuits. A normal (20k/volt) multimeter has a 50 microamp meter movement, and therefore draws a current of around 10 to 50 microamps from the circuit under test. This is obviously not possible in a low current part of a circuit where perhaps a current flow of only one or two microamps is present, and connecting the multimeter to the circuit has the effect of greatly reducing the voltage at the test point. Strictly speaking the voltage reading on the multimeter is correct, but the registered voltage is only present while the multimeter is connected to the circuit and is of little practical value.



The classic solution to this problem is to use a high impedance voltmeter when making voltage checks on low current circuits. A unit of this type has an amplifier to drive the meter and substantially reduce the input current requirement. This high impedance voltmeter design, in common with most units of this type, has a constant input resistance of over 11 megohms. Three voltage ranges having full scale values of 0.5, 5, and 50 volts are provided. In terms of ohms per volt sensitivity this gives over 22 megohms, 2.2 megohms, and 220k respectively, which is vastly superior to a normal analogue multimeter.

The first stage of the unit is a three stage attenuator which gives the three measuring ranges. R5, D1, and D2 are an overload protection circuit which prevents an excessive input voltage of either polarity from reaching IC1a, and also eliminates the possibility of an excessive input voltage causing a severe overload of the meter. IC1a, together with RV1 and D2 to D6, forms a precision full wave rectifier circuit which drives the meter. RV1 is adjusted to give the unit the correct level of sensitivity. The point of using a precision rectifier rather than a simple buffer stage is that it is then not essential to connect the input signal with the correct polarity. ME1 will register the correct input voltage regardless of its polarity. Note that IC1 is a type having a JFET input stage so that it does not significantly load the high resistance attenuator and impair the accuracy of the unit. C3 helps to filter out any noise picked up at the input, which (due to the fact the unit will respond to input signals of either polarity) could otherwise produce a strong deflection of ME1.

One problem with this basic voltmeter circuit is that it does not enable the polarity of the input signal to be determined. This is overcome by including voltage comparator IC1b and its associated circuitry. Under quiescent conditions or with a positive input signal (i.e. the non-earth input positive of the earth input) the output of IC1b goes high and LED indicator D8 is switched off. However, with a negative input signal the output of IC1b goes low and D8 is switched on to indicate that the input voltage is negative in polarity.

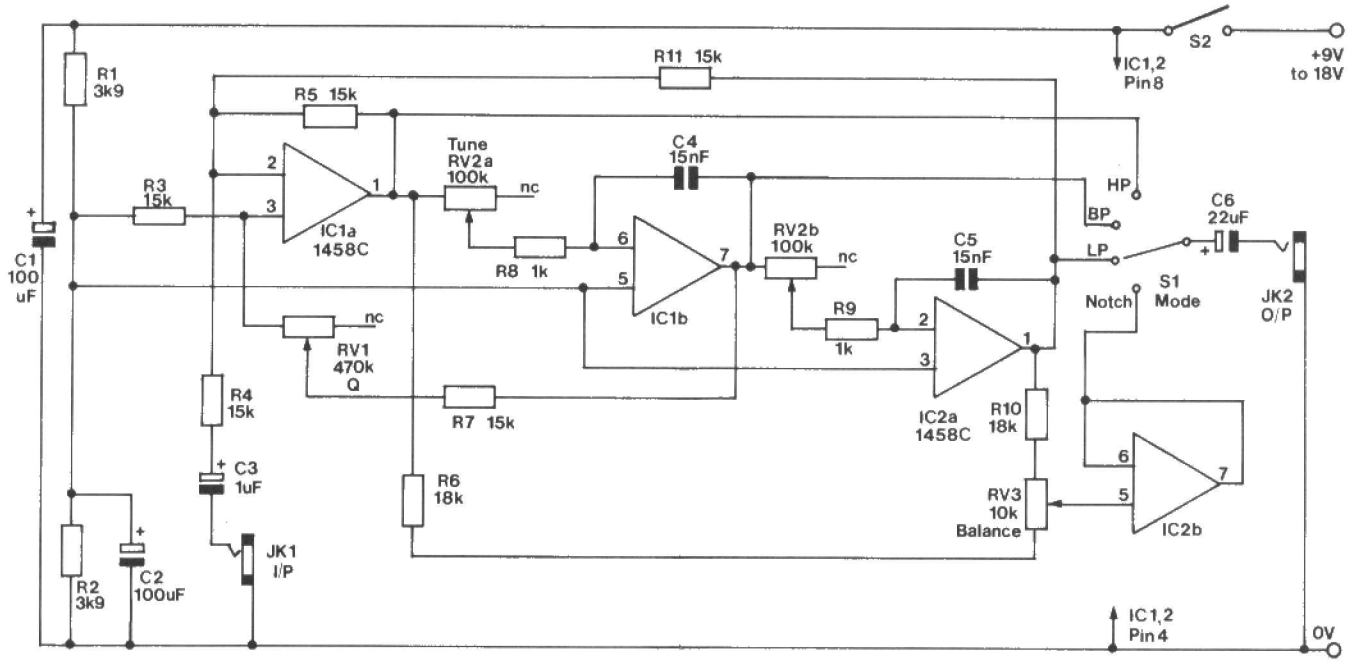
In order to calibrate the unit a suitable and accurately known voltage is required. For example, a 4.5 volt battery could be used to provide the calibration voltage. A multimeter would be used to measure the precise battery voltage, the high impedance voltmeter would be set to the 5 volt range, the battery would then be connected to the input of the unit, and finally RV1 would be carefully adjusted for precisely the correct reading on ME1.

DXER's State Variable Filter

With a communications receiver that lacks sophisticated IF filtering it is often possible to produce a worthwhile improvement in performance using an audio filter or filters. Issue 7 of this magazine featured a highpass/lowpass filter plus expander, but the design featured here uses an alternative approach which is in some respects more versatile (although, admittedly, in other respects inferior). The unit featured here is a state variable filter. In other words, rather than providing (say) lowpass and highpass filtering, it can be switched to give any form of simple filtering (highpass, lowpass, bandpass, and notch). In practice there would ideally be two or three filters connected in series so that several types of filtering could be provided simultaneously.

The circuit is a conventional state variable filter using four operational amplifiers. R1, R2, and C2 are used to provide a bias equal to half the supply potential so that the circuit can operate from a single supply having a potential of about 9 to 18 volts. IC1a acts as a mixer stage, while IC1b together with C4 plus the combined resistance of RV2a and R8 operates as a phase shift circuit. IC2a is connected in an identical phase shift circuit. Feedback paths are used to convert the phase shifts into a highpass filter action at the output of IC1a, a bandpass action at the output of IC1b, and lowpass filtering is obtained at the output of IC2a. R6, R10, and RV3 are used as a passive mixer which drives buffer stage IC2b. Mixing the highpass and lowpass outputs gives the notch filtering, and RV3 is a balance control which enables the unit to be adjusted for optimum attenuation. S1 is used to select the desired type of filtering, and RV1 is the 'Q' or 'resonance' control, according to which terminology you prefer. RV2 enables the cut-off or centre frequency of the filter to be adjusted (depending on the filter mode selected), and a wide frequency range of about 100Hz to 10kHz is covered. The filter is a two stage type and therefore has a 12dB per octave roll-off rate.

In use the unit is fed from the headphone socket of the receiver, and



the output will drive virtually any type of headphones at good volume. Lowpass filtering is useful for reducing adjacent channel interference, background 'hiss', and general background noise. Highpass filtering attenuates low frequencies, and can be useful in reducing low frequency heterodynes, mains hum, and any low frequency interference. With either of these types of filtering the tuning control is adjusted to minimise the interference without using so much filtering that the intelligibility of the signal is impaired, and it is usually quite easy to find a good compromise setting. The 'Q' control should be set at or close to minimum (i.e. set at almost minimum resistance), otherwise an unwanted peak will be produced in the frequency response close to the cut-off frequency.

Bandpass filtering is probably most useful during CW (Morse Code) reception. With the 'Q' control set at maximum RV2 is tuned to peak the wanted signal. Note that the voltage gain of the filter will be quite high in the centre of the passband, and the volume control of the receiver will therefore need to be well backed off in order to prevent overloading. An improvement in phone transmissions might be obtained using bandpass filtering with the 'Q' control set at minimum. The unit would then effectively provide both highpass and lowpass filtering, with RV2 being adjusted to give optimum results.

Heterodynes can be eliminated by setting the 'Q' control at minimum and then adjusting RV2 and RV3 to optimise attenuation of the unwanted tone. Advancing the 'Q' control helps to narrow the notch and minimise losses of the wanted signal, but adjustment of RV2 and RV3 then becomes somewhat more critical. There is also a danger of clipping occurring at certain points in the circuit, causing a loss of efficiency and distortion on the output. It is therefore advisable to keep RV1 well backed off when using notch filtering.

HIGH Z VOLTMETER PARTS LIST

RESISTORS – All 0.4W 1% Metal Film			
R1	10M	1	(M10M)
R2	1M	1	(M1M)
R3	110k	1	(M110K)
R4	1k1	1	(M1K1)
R5	12k	1	(M12K)
R6	10k	1	(M10K)
R7	1k2	1	(M1K2)
RV1	22k Hor S-Min Preset	1	(WR59P)
CAPACITORS			
C1,2,3	100nF Polyester	3	(BX76H)
SEMICONDUCTORS			
IC1	LF353	1	(WQ31J)
D1,2	BZY88C2V7	2	(QH00A)
D3-7	1N4148	5	(QL80B)
D8	Red LED	1	(WL32K)
MISCELLANEOUS			
ME1	50μA Panel Meter	1	(RW91Y)
S1	Rotary Sw 4-pole 3-way	1	(FH45Y)
S2	DPST Rotary	1	(FH57M)
JK1	3.5mm Jack	1	(HF82D)
B1,2	Battery 9V PP3	2	FK62S
	Battery Connector	2	(HF28F)

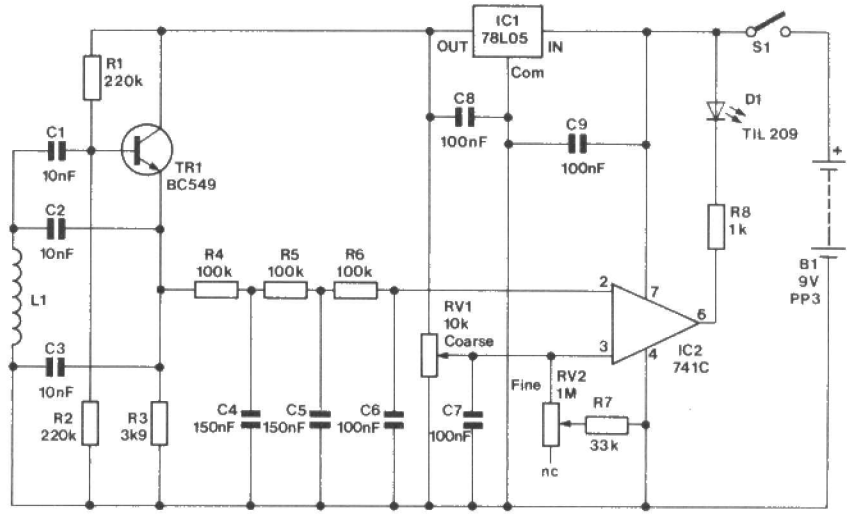
DXER's STATE VARIABLE FILTER PARTS LIST

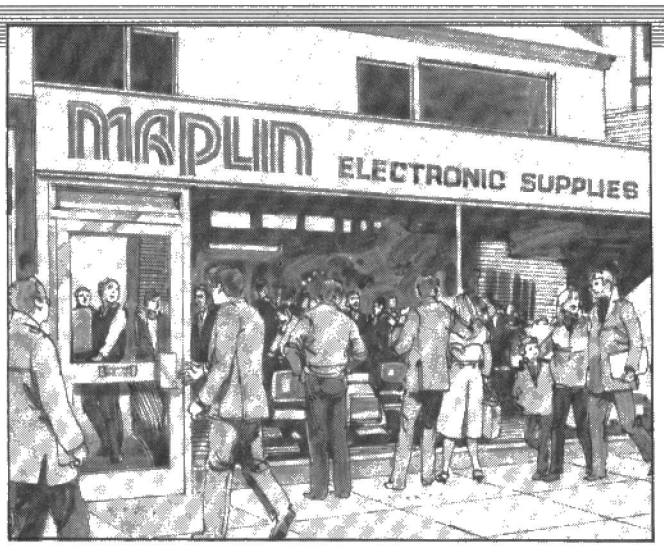
RESISTORS – All 0.4W 1% Metal Film			
R1,2	3k9	2	(M3K9)
R3,4,5,7,11	15k	5	(M15K)
R6,10	18k	2	(M18K)
R8,9	1k	2	(M1K)
RV1	Pot Lin 470k	1	(FW07H)
RV2	Dual Pot Lin 100k	1	(FW88V)
RV3	Lin Pot 10k	1	(FW02C)
CAPACITORS			
C1,2	100μF 25V Axial Electrolytic	2	(FB49D)
C3	1μF 63V Axial Electrolytic	1	(FB12N)
C4,5	15nF Carbonate	2	(WW31J)
C6	22μF 25V Axial Electrolytic	1	(FB30H)
SEMICONDUCTORS			
IC1,2	1458C	2	(QH46A)
MISCELLANEOUS			
JK1,2	¼in. Jack Socket	2	(HF91Y)
S1	Rotary Switch 3-pole 4-way	1	(FH44X)
S2	SPST Ultra-min Toggle	1	(FH97F)

Simple Metal Locator

This is an unusually simple and inexpensive metal locator design, but it is suitable for use as a pipe locator, treasure hunting, etc., and has a level of performance that is at least as good as the more usual BFO type detectors. Large metal objects can be detected at ranges of up to about 300 to 500 millimetres, and small objects such as coins can be detected at a range of 50 millimetres or so. The unit provides a clear and unambiguous indication if metal is detected – it switches on a LED indicator light.

The circuit is basically just an L – C oscillator operating at about 65kHz, plus a voltage comparator circuit. The circuit makes use of the fact that a metal object near the search coil (which is the inductive component in the L – C oscillator) produces a change in Q. This Q change is





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In the Midlands our Birmingham store is just 5 minutes from the M6 on the A34, and only a little farther from the M5 (junction 1) on the A4040.

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Our self-service store in Manchester serves the North and is just off the Mancunian Way, opposite the BBC, about 5 minutes from the end of the M602 or junction 10 on the M63.

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Essex and Kent are served by our Southend shop which is right on the A13, just 2 minutes before you reach the centre of Southend. And we're only 30 minutes from the M25 (junction 29) as well.

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MAGNIFICENT SEVEN

reflected in the strength of oscillation, which is in turn reflected in a shift in the average voltage levels in the circuit. The voltage comparator is used to detect this voltage shift and activate an indicator LED.

TR1 is used in the oscillator, and it is connected as an emitter follower stage. L1 acts as a tuned circuit in conjunction with C2 and C3, with these two capacitors providing a capacitive centre tap on the tuned circuit. This enables a voltage step-up through the tuned circuit to be obtained so that oscillation can be sustained despite the fact that TR1 provides slightly less than unity voltage gain. R4 to R6 and C4 to C6 form a three stage passive lowpass filter, and this provides a DC output voltage that is equal to the average voltage at the emitter of TR1. This voltage is coupled to one input of operational amplifier IC1, while RV1 supplies a variable reference voltage to the other input. In this application IC1 acts as a straightforward voltage comparator, and RV1 is adjusted so that the reference voltage is just marginally higher than the output from the filter. This sends the output of IC1 high so that LED indicator D1 is switched off. A piece of metal close to the search coil results in the output from the filter dropping to a lower potential than the reference voltage, which in turn causes the output of IC1 to go to the low state and switch on D1.

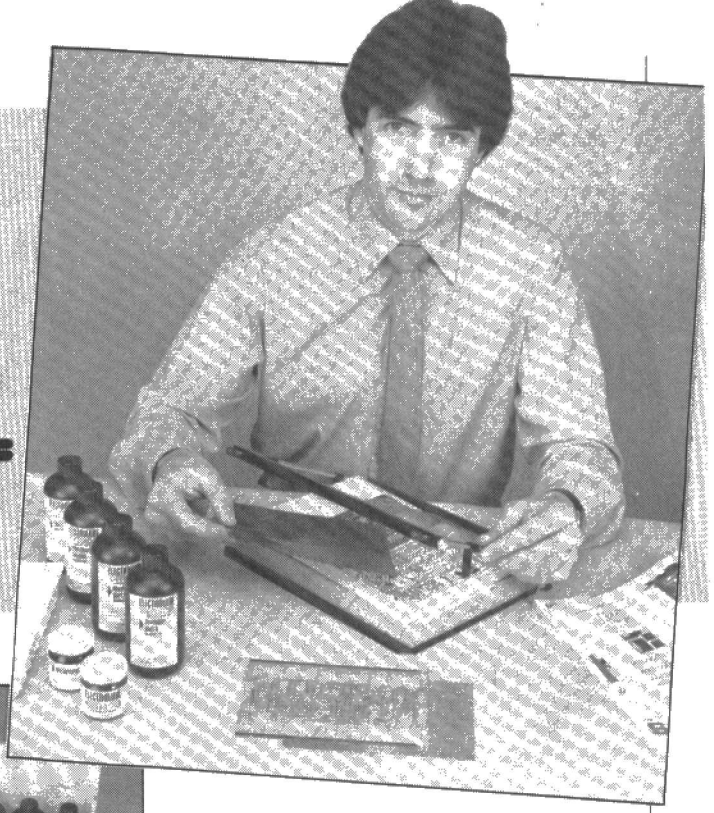
In practice it is essential (in the interests of good performance) to adjust the reference voltage to just a minute fraction of a volt less than the quiescent output level from the filter, and this is difficult using RV1 alone. A fine adjustment control has therefore been provided in the form of RV2. A stabilised 5 volt supply is used for critical parts of the circuit so that frequent readjustment of RV1 and RV2 is not required.

Electrically construction of the unit is mostly quite straightforward, but mechanically the design must be varied to suit the particular application you have in mind. From the electrical point of view the only difficulty is L1 which must be wound by the constructor. On the prototype this coil consists of 70 turns of 22 swg enamelled copper wire wound on a temporary coil former (an old plastic case) measuring 120 by 80 millimetres. Bands of tape can be used to prevent the coil from unwinding when it is removed from the temporary former. It is useful to shield the coil and connect the shield to the negative supply rail. A shield can merely consist of some aluminium foil wrapped around the coil and completely covering it. This should help eliminate any problems with ground capacity effects. With this design the exact size and number of turns on the coil are not critical factors as the exact operating frequency of the oscillator is unimportant.

SIMPLE METAL LOCATOR PARTS LIST

RESISTORS – All 0.4W 1% Metal Film			
R1,2	220k	2	(M220K)
R3	3k9	1	(M3K9)
R4,5,6	100k	3	(M100K)
R7	33k	1	(M33K)
R8	1k	1	(M1K)
RV1	Lin Pot 10k	1	(FW02C)
RV2	Lin Pot 1M	1	(FW08J)
CAPACITORS			
C1,2,3	10nF Carbonate	3	(WW39G)
C4,5	150nF Polyester	2	(BX77J)
C6,7,8,9	100nF Polyester	4	(BX76H)
SEMICONDUCTORS			
IC1	μA78L05AWC	1	(QL26D)
IC2	μA741C	1	(QL22Y)
TR1	BC549	1	(QQ15R)
D1	Red LED	1	(WL32K)
MISCELLANEOUS			
S1	SPST Ultra-min Toggle	1	(FH97F)
B1	Battery 9V PP3	1	(FK62S)
L1	See text		
	Battery Connector	1	(HF28F)

THE CM100 CIRCUIT MAKER KIT



If you enjoy building electronic projects, why not expand your hobby by actually making your own printed circuit boards! Most electronics magazines show full size board layouts that can be used as templates from which you can etch your own boards. All you need is a little knowledge and the right equipment. Undoubtedly, one of the best circuit building kits available at the moment is the Electrolube CM100.

The great advantage of the CM100 photographic development system is that professional quality circuit boards can be produced without a darkroom, camera equipment or ultra violet lights, and the ease of use makes previous photographic experience unnecessary.

The CM100 – Circuit Maker Kit was one of the first kits on the market to offer a complete and easy-to-use system for producing printed circuit boards. There are four main stages to making PCB's with the CM100. The first step includes choosing a circuit layout design and producing a film over the PCB design and then exposing it with a photoflood bulb. The film is then developed in the chemicals provided in the CM100. After clearing the film of any 'greyness' with clearing solution any small flaws can be touched in with a retouching pen and the builder is ready for the next stage which involves the actual production of the printed circuit board.

In this stage the copper clad board is thoroughly cleaned with a scouring pad because any traces of dirt or grease will prevent the photoresist from adhering to the copper, prevent proper etching and cause blemishes. Photoresist is then applied to the board with a plastic sponge applicator. To some it may be argued that this is the most difficult part of the process and that using pre-coated boards is easier, but there are three major reasons for this method of application.

The first and most important reason is that if any errors occur while exposing the pre-coated board they cannot be corrected. The second reason is that the added cost of using pre-coated boards makes the total production process less economical. Finally, the manual method of application allows the builder the personal satisfaction of seeing the project through completely from start to finish.

Conversely in the CM100 Kit, photoresist can easily be removed by using the scouring pad provided or photoresist developer concentrate (also part of the Kit). Thus the PCB builder has more than one chance to correct mistakes if the need arises. For the builder looking to cut down on production time, an aerosol photoresist will soon be available from Electrolube.

The next step after the film positive master and board are exposed and developed to reproduce the circuit layout, is etching. This is completed by preparing an etching solution in a long, narrow and very thick plastic bag. Using slide clips to section off the bag, the board is then inserted into the solution (which can be used again), and the bag and solution are then gently agitated to encourage etching. When the etching is completed the board is rinsed and left to dry.

The final stage of the process involves removing the photoresist which is left to protect the circuit tracking. Using the photoresist developer concentrate and a cotton wool ball, the board is wiped clean of the last traces of photoresist. Once rinsed and dried the copper tracks are coated with flux lacquer by means of the special applicator holder. This lacquer prevents oxidation and makes soldering easy and reliable.

The printed circuit board is now ready for drilling and component assembly. The Universal Assembly Frame which is also used for the production of film positive masters as an exposure frame can now be used as a component assembly frame. The foam backing which is heat resistant, is used to clamp the components to the board and thus prevents the components from dropping out of the board while lead cropping and soldering take place.

The CM100 – Circuit Maker Kit is a very useful asset for electronic hobbyists, colleges and educational institutions and small scale research and development centres because it produces an extremely versatile system which can be used to produce circuit layouts from magazines and other sources. The Kit is also very adaptable and can be tailored to suit the needs and demands of various situations.

In response to the ever-changing needs of the electronics market, Electrolube will now offer kit items as separate products which will allow hobbyists, colleges and educational institutions, and research and development centres to supplement their existing equipment and supplies. One of the key additions to the Circuit Maker Kit list of products is larger sized positive photographic film up to 30cm x 40cm. This new size allows the pcb builder more flexibility when choosing the dimensions of a circuit board since it is possible to cut the film to any desired length and width. Further items to be offered separately from the CM100 are a specially designed Universal Assembly Frame, developers, fixer and clearing solutions for the auto-positive film, photoresist and developer, and double-sided copper clad boards.

The CM100 – Circuit Maker Kit usually sells for around £70 but Maplin are currently selling it on special offer at £49.95; see the special offer section in this magazine. Maplin are also now selling the Kit items separately; refer to page 213 of the new 1985 Catalogue for details.

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